

Mini-implants in Orthodontics

Innovative Anchorage Concepts

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Introduction

Lex tertia: Actioni contrariam semper et aequalem esse reactionem: sive corporum duorum actiones is se mutuo semper esse aequales et in partes contrarias dirigi.

Sir Isaac Newton, 1687

Many years have elapsed since *Isaac Newton* phrased his four axioms that established him as one of the greatest scientists in human history. Before *Newton*, people only knew that some things worked and some did not. Only after publishing the book "*Philosophiae Naturalis Principia Mathematica*" (1687) – "*Natural Philosophy of Mathematical Principles*" – did the world understand the reason for many observed phenomena, such as why things drop to the ground (or why an apple falls from a tree). His third law of physics (*action = reaction*) is so important in the orthodontic specialty as it explains many of the phenomena we observe during treatment; however, it does not solve any of our mechanics problems. Not even skeletal anchorage, the topic of this communication, can change the basic principles of physics; rather, mini-screw anchorage permits us to use *Newton's* principles to our advantage. Therefore the objective of this book is to explain how we might make "*action = reaction*" work in our favor and, as a result, move teeth more efficiently and predictably.

Ever since its conception more than a century ago, our specialty has been focused on the importance of anchorage and the consequences of its loss. The often undesirable effects of reactive forces have been an area of constant concern. For instance, functional orthodontic appliances may produce unwanted protrusion of the lower anterior teeth that support these devices. When using removable plates, undesired reciprocal effects (tipping of the teeth) can be observed in the dental units used as anchorage. Even when using full fixed appliances, certain groups of teeth are pitted or

anchored against others. Side effects of tipping or unintended loss of space can be observed depending on how well the biomechanics are designed and controlled. All manner of anchorage control concepts have come and gone in the ensuing years, including *Baker* anchorage, headgears, lip bumpers, *Nance* holding arches, tip-back bends, lingual arches, uprighting springs, sectional mechanics, dual arch mechanics, and elaborate mechanisms to "set anchorage". By now the observant reader and experienced orthodontist have realized that no current treatment philosophy, no matter how intelligent and complicated, can prevent all reciprocal treatment effects (or anchorage loss).

In the 19th Century, concepts were designed to anchor teeth to structures other than teeth within the same or even the opposite jaw. These ideas led to the development of extraoral anchorage systems. The era of skeletal anchorage began later, in 1945, with the failed experiment of *Gainsforth* and *Higley*² to anchor screws in the jaws of mongrel dogs and to move teeth against these fixed anchorage units. After other similar experimental efforts failed, this anchorage method did not appear to be a viable clinical alternative until it was revisited by *Creekmore and Eklund*¹, *Roberts et al*³⁻⁷, and *Turley et al*^{8,9}, starting in the 1980s. Their in-depth clinical and animal experimental investigations established the base for today's use of skeletal anchorage techniques.

Subsequent case reports and studies have clearly demonstrated that teeth can be moved without undesired effects on other groups of teeth when skeletal anchorage is employed



Fig. 1-1 and 1-2 Mesialization and intrusion of the mandibular left second molar using implant anchorage. The provisional crown is anchored on a dental implant.



Fig. 1-3 and 1-4 Distalization stabilized by skeletal anchorage from a palate implant (photos by Dr. B. Wilmes, Düsseldorf).



Fig. 1-5 and 1-6 Orthopantomogram and clinical picture shows the functional application of osteosynthesis mini plates as skeletal anchorage. The latter represent effective measures against reactive intrusion. (photos by Dr. B. Wilmes, Düsseldorf)

(Fig. 1-1 and 1-2). This use of skeletal anchorage appears to be quite convenient, perhaps even "luxurious", when costs, risks, and limited indications are considered. *Wehrbein*¹⁰⁻¹² and *Glatzmaier*^{3,4} first introduced an implant system specific for orthodontic use (Orthosystem, Straumann). These implants, including the Midplant (HDC), were predominately inserted into the palate. Fig. 1-3 and 1-4 show that precisely directed distalization using a palatal implant is possible without the typical side effects of anchorage loss. This method is still being used successfully today; however, due to the more involved surgical procedures for osseointegrated implant placement and removal, they are not feasible for routine application in private practice, where a quick and simple insertion is required.

Many other skeletal anchorage solutions exist that have also been proven successful in clinical practice (Fig. 1-5 to 1-7). Some of these were adopted from OMFS but are also not very applicable in private practice, due to the more invasive nature of the insertion and removal procedures.

All systems for skeletal anchorage use some type of implant: "An implant is an artificial object inserted into the human body which remains there either permanently or for an extended period of time." The medical products law distinguishes between short- and long-term implants. The limit is set at 30 days retention time in the body. For both classifications, different laws and regulations exist.

This communication deals exclusively and in-depth with mini-screws (sometimes also

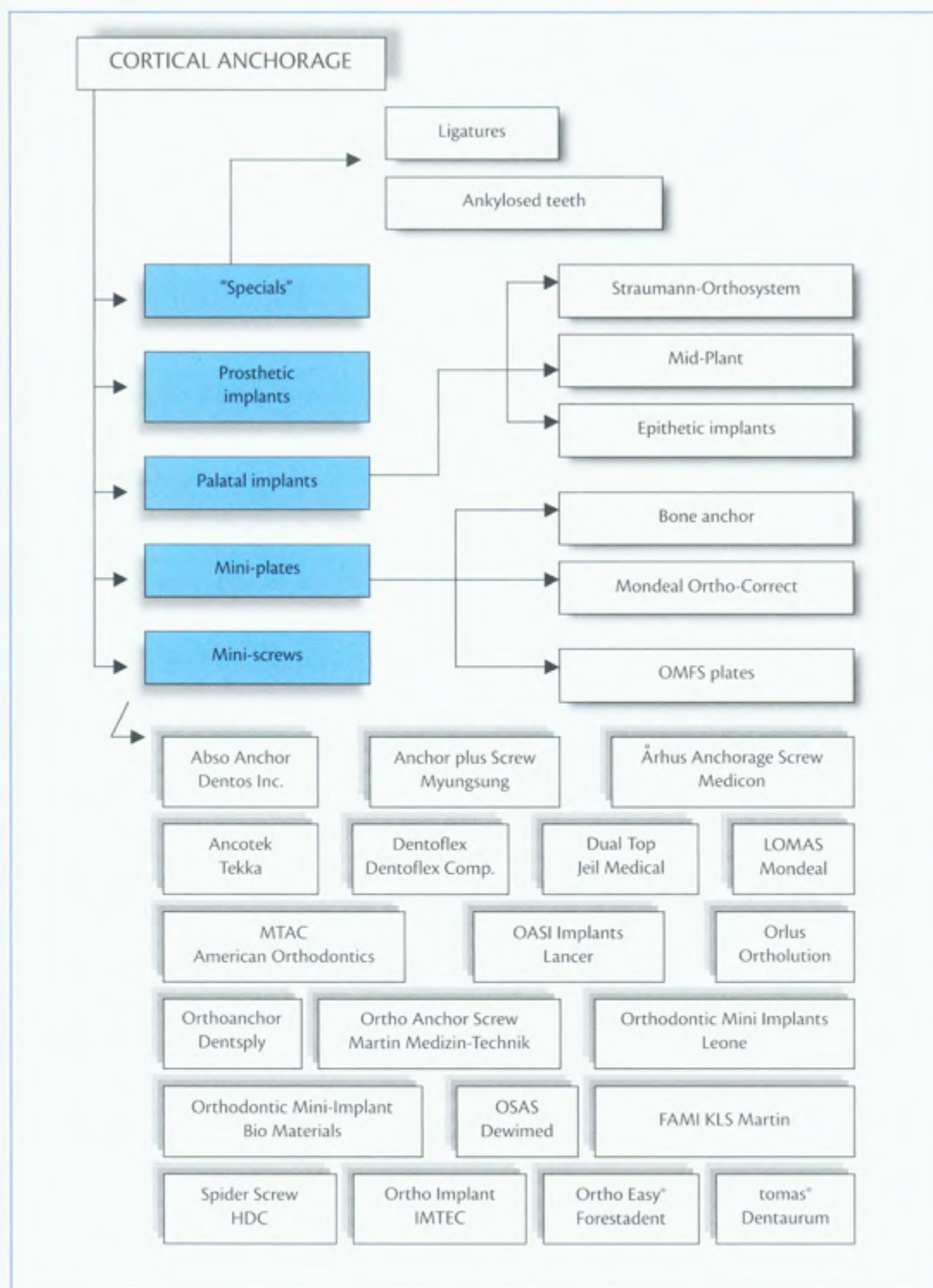


Fig. 1-7 Graphic representation of the various types of cortical anchorage.

called temporary anchorage devices, or TADs) as a relatively simple form of skeletal anchorage. Mini-implants, mini-screws, pins, TADs, micro-implants, or whatever other nomenclature may be used (Fig. 1-9), these devices certainly appear poised to be one of the most significant changes in the clinical practice of orthodontics in our history.

We wrote this book to share our enthusiasm for these little mini-screws with you, as they finally permit orthodontists to have a reliable fixed anchorage point. As a result, our biomechanics become more predictable and we can treat some patients in a manner that was either impossible or at least unlikely in the past. Our intent is to introduce our colleagues



Fig. 1-8 Orthodontic space closure with skeletal anchorage via mini-implant (Glasl B, Ludwig B).

- microimplant
- micro-implant
- Micro-implant anchorage
- Microscrews
- mini implants for orthodontic anchorage
- mini screw
- mini-implant
- mini-implant for orthodontic anchorage
- mini-implant system
- mini-screw
- miniscrew
- Mini-screw anchorage system
- miniscrew implant
- Ortho implant
- Orthodontic anchorage implant
- Orthodontic anchoring implants
- Orthodontic implants
- orthodontic mini implants
- Orthodontic miniscrews
- Ortho TAD
- skeletal anchorage system
- Small titanium screws
- TAD - Temporary Anchorage Devices
- titanium implant anchorage
- titanium microscrews
- titanium mini-implants
- titanium screw anchorage

Fig. 1-9 List of common terms used for mini-screw implants.

(orthodontists, general dentists, oral surgeons, and periodontists) to some exciting and new treatment methods. We hope you consider this a guidebook or manual to familiarize the beginner with the subject. We also intend to expand the knowledge base of the advanced operator by pointing out potential pitfalls and proposing alternative approaches to interesting clinical situations.

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The Problem of Anchorage

2.1 Tooth Movement and Anchorage

The movement of teeth within the scope of orthodontic treatment occurs through the application of forces. In order for these forces to affect a change in tooth position, adequate support ("anchorage") must be available from which to apply those forces. This support can be derived from other teeth or from skeletal structures. These forces act reciprocally on the teeth that are intended for movement, and also upon those structures used for support via Newton's Third Law.

If other teeth are used to support tooth movement, then the equal and opposite forces are applied to the teeth intended for movement and also to the anchor teeth. This may result in unintentional or adverse changes in anchorage support. The extent of these changes in both sets of teeth depends on the strength of the abutment: the number of teeth, their root length and form, cross section, and surface area. In addition, the quality of the supporting bone also plays a role in the anchorage.

In some instances, reciprocal movement of the supporting teeth is acceptable or even desirable. This happens, for example, with the sagittal expansion of a dental arch where the front teeth will be protruded and the lateral teeth will be distalized. Likewise, the movement of the anchorage teeth is to be accepted during the transverse expansion with steady lateral movement of the right and left posterior teeth or with reciprocal space closure when anterior and posterior move toward each other over about the same distance.

Anchorage support can occur using teeth

within the same jaw (intra-arch), derived from teeth in the other dental arch (inter-arch), or based on support from skeletal structures other than the teeth. If the forces affect only the teeth that are intended for movement, this is called stationary support.

Examples of an *intra-arch anchorage* include: opening spaces between teeth using springs, the protrusion of anterior teeth using posterior dental support, transverse expansion of the dental arch, and space closure using closing loops, elastic chain or coil springs. Examples of *inter-arch anchorage* would include Class II or Class III intermaxillary elastics. **Anchorage-support that is independent of teeth** can be derived from extra-oral devices (e.g. headgear or facial mask), by support from the musculature (e.g. lip bumper) or from skeletal anchorage (e.g. dental implants, mini-plates, or mini-screws).

If no reciprocal movement of the anchorage support is desired, then stabilization of the supporting dentition is critical (Fig. 2-1). For example, the extraction of premolars and retraction of anterior teeth is often necessary for patients with severe protrusion and/or crowding. Mesial movement of the molars and second premolars is undesirable if maximum retraction of the anterior teeth is required to resolve the dental discrepancy, to eliminate the overjet, or if substantial improvement in lip protrusion is desired. In these instances, it is imperative that the posterior supporting teeth are held in their original position (i.e. maximum anchorage).

Situations where some mesial movement of the supporting teeth can be tolerated during space closure are termed medium anchorage. Sometimes minimal anchorage is required when mesial movement of posterior teeth is

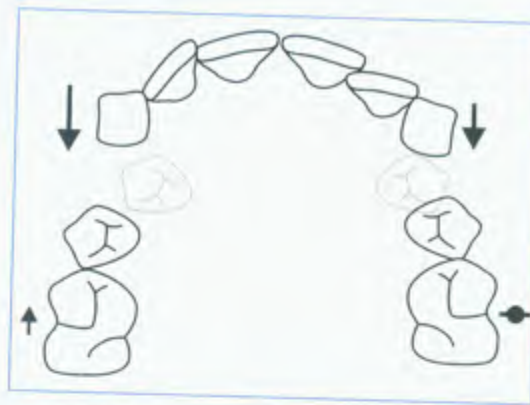


Fig. 2-1 Mesial movement of upper molars is often an undesirable by-product of retraction mechanics.

desired during extraction space closure – this is called “slipping anchorage”.

Maximum anchorage may also be required when uprighting inappropriately inclined teeth, to regulate displaced teeth, to assist with intrusion or extrusion of teeth, to support the opening of spaces, and for support of many dentoalveolar movements. It is important that only the teeth intended to be moved actually change position while the remaining teeth remain stationary.

2.2 Types of Anchorage

Anchorage may be achieved in many different ways:

- a) extra-oral support (headgear or facial mask)
- b) intra-oral appliances (Nance holding arch, palatal arch, lingual arch, lip bumper)
- c) modification of fixed devices (buccal root torque, uprighting springs, tip-back bends (“setting anchorage”), gable bends, torquing auxiliaries)
- d) support from teeth in the opposite dental arch (Class II or III intermaxillary elastics)
- e) skeletal anchorage (dental implants, mini-plates, mini-screws).

Absolute anchorage or stabilization of specific teeth can be achieved using implants or mini-screws. Mechanisms that rely upon other teeth as anchorage support provide only relatively stationary anchorage, as reciprocal forces may still affect the teeth that are not intended

for movement. Some methods of anchorage rely upon unpredictable patient compliance with appliances or devices such as intermaxillary elastics, headgear, and facial masks.

a) Extra-oral Support

Extra-oral devices like headgear (Fig. 2-2) or the facial mask (Fig. 2-3) derive anchorage from the external cranial structures (i.e. back of the head, forehead and chin). The “headgear” concept for extra-oral anchorage was demonstrated by *Kingsley’s head-cap* in 1866⁵. *Angle*¹ also described similar devices. In 1936, *Oppenheim* systematized extra-oral devices and re-introduced them in the USA. The most common type of headgear used today to distalize and/or stabilize maxillary first molars can be attributed to *Kloehn*⁶ in 1947. To stabilize molars, a force of 200 g is required, but more important than the magnitude of force is the duration; headgear must be worn a minimum of 12 hours per day. Consequently, the success of headgear anchorage is completely dependent upon patient compliance.

Face mask or reverse-pull headgear achieves anchorage from contact to the patient’s forehead and chin, as described by *Delaire*^{2,3}. This type of extra-oral anchorage is used to support protraction of the maxilla and maxillary dentition. These two types of extra-oral devices preclude adverse effects (reciprocal movement). The trade-off is unpredictability predicated on the cooperation level of the patient.

b) Intra-oral Anchorage Devices

A variety of intra-oral appliances have been introduced to assist in supporting tooth movement. Unfortunately, these devices are limited in their capacity to provide stable anchorage.

The *Nance holding arch* (Fig. 2-4) pits the molar teeth against the anterior palate. Typically, this appliance is constructed using bands on the maxillary molar bands. An acrylic button, with a stainless steel palatal arch soldered to the bands, is braced against the sloping portion of the anterior palate to resist mesial movement of the molars. Although this device was originally intended to prevent mesial migration of molars as a space maintainer, it has also been used as anchorage support, independent from patient compliance,



Fig. 2-2 Cervical headgear.



Fig. 2-3 Delaire facial mask.



Fig. 2-4 Nance holding arch.



Fig. 2-5 Transpalatal arch.

during retraction of anterior teeth in extraction cases. Caution is warranted as debris may accumulate under the acrylic "button", and tissue impingement can result. A modification of this anchorage concept has been seen with so-called molar distalizing appliances from *Cetlin*, *Gianelly*, *Jones' Jigs*, *Carano* and *Testa's Distal Jet*, and *Hilgers' Pendulum*⁴.

The transpalatal arch (TPA), also known as a palatal bar or *Goshgarian arch* (Fig. 2-5), consists of a rigid stainless steel wire, following the contours of the posterior palate, connected to bands on both first molars. Often these arches have an omega-shaped loop in the mid-palate for adjustment purposes. The transpalatal arch

has been suggested as a means for molar support as the molars on both sides of the dental arch are "tied-together" as an anchorage unit. Mesial movement of the molars during active retraction of the anterior dentition is said to be prevented because molars are held at a specific transverse dimension. As the first molars are protracted slightly into the narrow part of the maxilla by reciprocal force, the mesiobuccal roots encounter cortical bone, which impedes their movement. The effect is independent of compliance; however, it is not absolutely stationary. In fact, the TPA provides rather poor anchorage for retraction, but serves nicely to assist in supporting intrusion arches (e.g.



Fig. 2-6 Mandibular lingual arch.

Ricketts' Utility Arch) for reducing deep overbites. In addition, the TPA has assisted in maintaining arch width (to limit unwanted expansion or constriction) and it has also been used to actively rotate or torque the molars.

The lingual arch (LLA) and lip bumper have been used to help prevent the mesial movement of mandibular molars. The lingual arch (Fig. 2-6) consists of a stainless steel wire that follows the lingual surfaces of the mandibular teeth. This wire is attached to bands on the first molars. The LLA passively contacts the lingual surface of the mandibular anterior teeth in the cervical third of the crown. In this manner, the position of the mandibular incisors is braced against the lower teeth. They, in turn, are supported by the musculature of the lower lip. Like the *Nance* holding arch, the lingual arch was originally introduced to prevent mesial migration or tipping of the mandibular molars, impinging upon the leeway space, after premature loss or extraction of deciduous molars in the mixed dentition. The LLA has also been used as anchorage support for retraction of canines and to resist the mesial rotation and mesial *en masse* movement of the mandibular dentition as adverse side effects of intermaxillary Class II elastics or from fixed functional appliances. Although patient compliance is not an issue with the lingual arch as it is cemented or luted in place, the degree of anchorage support from the mandibular anterior is unpredictable as these teeth may simply tip labially, permitting mesial molar movement.

The lip bumper is not just a labial version of the lingual arch, although at first glance it may appear as such. A lip bumper typically consists of a continuous round stainless steel wire that extends from bands placed on both mandibular first molars. Although the lip

bumper can be fixed into tubes on those bands, most often the device is removable so that patients may have better access for oral hygiene. Often an acrylic vestibular pad is fabricated around the wire in the anterior region. The lip bumper is constructed with the wire portion approximately 4–5 mm away from the buccal surfaces of the mandibular dentition. As a result, the lip bumper impinges upon the drape of the oral musculature. It is the force from the muscles that is transmitted through the wire arch to the molars which provides anchorage support to prevent their mesial migration. In the natural state, forces from facial muscles and tongue are said to be balanced and the patient's natural dental arch form results. With a lip bumper, the forces from the facial muscles are withheld from acting on the buccal surfaces of the teeth, the pressure from the tongue then expands or "develops" the width of the mandibular dental arch.

Again, success with the lip bumper as either a space maintainer or as anchorage support is dependent upon patient cooperation (unless the device is fixed in place). Some mandibular molar distalization or uprighting has been shown when patients are exceptionally cooperative. Successful resistance to mesial *en masse* movement when the lip bumper is used with intermaxillary elastics or fixed functional appliances (e.g. *Herbst* or *Jasper Jumpers*) has not been documented.

c) Anchorage Support from Buccal Root Torque or Blocking

Changing the angulation of the roots of teeth has been promoted as a hallmark of "anchorage preparation" for decades. The simplest method is the simple tip-back bend (most often placed in a continuous orthodontic arch wire just mesial to the first molars) or series of tip-backs (e.g. *Tweed* anchorage). The concept is based on the premise of the "tent peg", whereby a stake is driven into the ground, angled away from the tent, to provide support for the ropes that are attached to the fabric of the tent. In this manner, the tent peg must be moved through more supporting ground in order to be dislodged than if the peg were driven in perpendicular or at an angle towards the tent. In the former, the forces required to remove it are applied per-

pendicular to the long axis of the peg. In the latter, only a small amount of force parallel to the long axis of the peg is required.

Anchorage support has also been proposed by producing buccal root torque of the posterior teeth with the intent of pushing the buccal roots into the cortical plate. Tooth movement would then be resisted by the denser bone.

The use of labial root torque applied to the anterior teeth is another method that has been used to reduce distal movement of these teeth when mesial movement of posterior teeth is desired.

Finally, the concept of blocking groups of teeth together as a kind of "large tooth with multiple roots" has been combined with many of the previously mentioned methods. Anchorage "units" have been constructed by connecting together several teeth (e.g. tying together the second premolar with the first and second molar to resist their mesial movement during retraction of anterior teeth). This is based on the idea that teeth with a larger root surface area (molars) are more resistant to movement than those with smaller roots (incisors). Therefore, blocking together several teeth with larger root surfaces would be theoretically even more resistant to movement. In fact, if these teeth were first tipped back and their roots torqued into the buccal plate, they would be exceedingly resistant to movement. Unfortunately, achieving these "preparatory" tooth movements has anchorage requirements nearly as stringent (often requiring substantial patient compliance) as the intended procedures for which the anchorage is to be set up.

Unfortunately, despite our best efforts and most elaborate dental-based anchorage constructions, teeth move in response to reciprocal forces. *Tweed* said that the "best anchorage is from an undisturbed tooth" and *Melsen* reiterated this by stating that "previously mobilized teeth" are poor sources of anchorage.

d) Intermaxillary Anchorage Support

Since reciprocal intra-arch forces can result in unintended tooth movement (i.e. anchorage loss), intermaxillary forces (from one dental arch to the other) may assist in reducing these adverse changes. For example, Class II or III elastics can be used to support the retraction

or protraction of teeth without "stressing anchorage" in the arch where the intended movement is to take place. Unfortunately, the vertical component of force from intermaxillary elastics may cause unwanted extrusion in both arches and/or *en masse* mesial or distal movements of teeth in the opposing arch.

Fixed functional appliances like the *Herbst* or *Jasper Jumper* have also been used for intermaxillary anchorage support. For instance, maxillary molars can be supported during anterior retraction or mandibular incisors can be held upright during protraction of posterior teeth through the application of fixed functionals. Although these fixed devices do not depend upon patient compliance to provide anchorage support, they are bulky, limit normal function, subject to breakage, and can produce adverse or unintended effects (i.e. labial "flaring" (tipping) of mandibular anterior teeth).

e) Skeletal Anchorage

Skeletal anchorage can be derived from typical dental implants (osseointegrated dental analogues), surgical fixation wires, surgically-placed mini-plates or "on-plants", or with non-osseointegrated mini-screws (also called temporary anchorage devices (TADs), a term coined by *Dr. George Anka*). Skeletal anchorage support does not require patient compliance, permits the incorporation of often simple biomechanics, and provides more predictable, efficient and effective treatment options.

It appears that the history of orthodontics has been littered with a plethora of anchorage concepts, mechanisms, devices, and appliances. Interestingly enough, each of these anchorage procedures or philosophies was probably successful enough at one time to satisfactorily treat many malocclusions. Unfortunately, reliance upon patient compliance, elaborate biomechanics, and unpredictability contributed to the relegation of many of these strategies to our history books.

It is the purpose of this text to describe the application of skeletal anchorage, in the form of mini-screws, as the next step in the continuing evolution of orthodontia. From the rationale for using TADs to their design, insertion, and application, several authors have been invited to provide their insight in this significant paradigm shift.

2.3 References

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Mini-screws – Aspects of Assessment and Selection Among Different Systems

3.1 Introduction

The advent of temporary skeletal anchorage may eventually be considered as significant to the specialty of orthodontics as was the introduction of pre-adjusted appliances, composite bonding of brackets, super-elastic wires, etc. The careful first steps of incorporating temporary anchorage devices (TADs) into orthodontics appear to have been rapidly left behind for many of us. As a result, it is certainly not an exaggeration that cortical anchorage has already become an indelibly important part of contemporary orthodontic clinical treatment. The therapeutic possibilities for the application of mini-screws have increased dramatically since their introduction in 1988. Since 1995, the topic of TADs has seemed to propagate exponentially throughout the specialty's literature³⁴, manufacturer's marketing, and as one of the "hot topics" of continuing education seminars and symposia.

Before delving into the "how to" aspects of mini-screws, it might be useful to examine some properties for ideal skeletal anchorage as described by a number of authors^{34,67,84,117}:

- biocompatibility
- small dimension
- easy clinical application
- favorable primary stability and retention
- immediate loading
- sufficient stability for typical orthodontic forces
- applicable for use with contemporary orthodontic mechanics
- mechanics independent from patient compliance
- clinically equivalent or better results in comparison to customary anchorage methods
- easy removal
- reasonable cost

The different variations of current skeletal anchorage methods, like osseous wires^{110,151}, flat screws^{16,168}, orthodontic implants^{105,173}, plate systems^{49,50,84} and mini-screws, have some specific but often comparable indications for clinical use. All of these anchorage variations have their own inherent advantages and disadvantages but it seems that mini-screws completely meet the requirements for ideal skeletal anchorage as listed above. In comparison with other methods, mini-screws are the smallest, easiest to use, the least invasive, provide options for the most potential anchorage applications, and can be loaded immediately or soon after their insertion^{72,59,74,84,115}.

It appears that in the near future, mini-screws will become a routine part of daily clinical orthodontic practice as a conservative means of temporary skeletal anchorage. The other methods will likely be relegated to only specific applications. This prediction is supported by a constantly growing number of publications on the subject of mini-screws³⁴, as well as the increasing number of mini-screw systems entering the orthodontic marketplace³. At the present moment, there are more than 30 systems offered worldwide and presumably that number will increase dramatically in the near future. Recently, the focus in development of TADs has been squared on mini-screws alone.

In view of the large number of mini-screw systems that are already commercially available and soon to be introduced, selecting a particular system appears to be a daunting task for the discerning clinician. Consequently, at this juncture in the evolution of this technology, it looks as though a systematic survey of individual systems may be useful. Therefore, it is the aim of this chapter to introduce and assess many of the different products in an attempt

to assist the practitioner in making an informed decision. In the following chapters, a synopsis of the important aspects of mini-screw selection and application, in light of specific advantages and disadvantages, will be presented. In preparation for this investigation, *Cope*TM has already formulated some important questions for consideration:

- What are the ideal qualities for mini-screws in regards to length, diameter, head design, thread design, material, and surface treatment?
- Self-drilling, self-advancing, or self-tapping?
- What is the maximum loading capacity?
- Are microorganisms attracted to one surface design more than another?

Although these questions play an important role in the assessment of a specific system, there are still other aspects that may be significant for the clinician/consumer. For example, how well do the individual components of a system coordinate (e.g. driver/screw, auxiliaries/screw, mechanics/screw, etc.), what are the requirements for insertion, and what is the sequence of clinical steps for application of mini-screw-supported mechanics? It would seem critical that the insertion of mini-screws and the application of TAD-based mechanics will need to be simple, inexpensive, and require limited chair-side time in order to be seamlessly assimilated into routine clinical procedures. As a result, not only will the various mini-screws and the procedures for their insertion be compared with each other, but also any associated auxiliaries that are available and the steps required for their application will also be examined.

We hope to objectively answer the previous questions regarding the properties of each mini-screw system along with a discussion of their possible positives and negatives – independent of “trademarks”. However, where it seems sensible for the better understanding of a problem, positive but also negative examples will be described; at least as of the date of publication of this monograph.

As far as possible, the properties of mini-screws will be described on the basis of data from the current literature; an evidence-based approach. It is quite obvious that additional research and development are the “life blood” of the rapidly emerging field of mini-screws, and, in fact, may be the foundation on which the future of the orthodontic specialty will be built.

In the second part of the chapter, each mini-screw system is described in detail. In order to provide an objective description, a questionnaire (Appendix 3-01 and 3-02) was compiled, based on the previously listed criteria. This questionnaire was sent to all known mini-screw manufacturers. The results of the survey are reported without comment in an overview (Table 3-10).

Undoubtedly, there is no ideal mini-screw, but there are definitely systems that appear to demonstrate all of the important aspects. In contrast, it also seems that some systems may only fulfill the minimum requirements for consideration. Obviously, individual practitioner requirements and preferences will be important to the ultimate determination if a specific system is suitable for a particular practice and its patients.

As will become patently evident, numerous aspects have been taken into consideration to frame the following discussion. This should also be true when selecting a mini-screw system for clinical use. It is important to note, however, that the retail price of the products was not a factor in any of these comparisons. There are several reasons for this decision.

The marketplace for mini-screws is a rapidly expanding universe, with nearly every major orthodontic manufacturer aligned with their own mini-screw system. As new systems are introduced, some of them will appear to be simple derivatives of existing devices and the only differentiation may be a lower price to win market share. Consequently, profit margins and price points are not topics of discussion in this text. Factors such as patient safety, biocompatibility, and reducing the risks of iatrogenic effects would seem to be more important aspects of product selection and should not be pushed to the background in relation to cost. As *William Mayo* once stated, “The best interest of the patient is the only interest to be considered.”

3.2 General Aspects of Mini-screws

Since 2003, the number of mini-screw systems has seemed to increase exponentially, as have the number of associated introductory and hands-on courses, symposia, and international congresses. Websites and publications have

introduced and discussed many therapeutic solutions with mini-screws¹¹. In other words, an explosion of information regarding mini-screws is being swiftly disseminated throughout the specialty.

In the careful assessment of a particular mini-screw system, there are many factors beyond just the product itself. At first glance, many of these aspects may appear to be subordinate and/or insignificant. The following are examples of such factors:

Inventor

Why is it important to know who was the inventor or developer of a particular mini-screw? The effectiveness and efficiency of any system or device are important considerations when adopting a new technology in clinical practice. Therefore, it may be an advantage for the development of a mini-screw system to have been initiated or directed by an orthodontist (i.e. a mini-screw invented by a practitioner for practitioners). In Table 3-10, the different systems and their inventors or developers are listed. During subsequent research, development, and improvements, advice from practicing clinicians would seem to be invaluable, especially when combined with clinical research. These aspects are all very important to the marketplace, especially if discounted copies or "knock-offs" of previously introduced products become prevalent.

Certification

Mini-screws are implantable medical products and have been designated as Class IIb devices in European medical products law. Therefore, within the European Union, the CE-certification will be indicated by the appropriate CE-sign and as such, mini-screws that are not CE-certified may not be sold in the European Union. In almost all countries of the world there are similar licensing procedures. In the USA, the approval for these products is accomplished through the Food and Drug Administration (FDA).

This type of licensing requires that the manufacturer or distributor must submit specific documents to describe not only the properties of the product and its intended indications and applications, but also any associated risks.

The licensing entity will then determine the

applicability of associated regulations. The resulting certification will inform the user whether the particular product meets these regulations. The quality of each device is not individually checked, but rather the continuity of quality is determined. As a result, the decision to use an approved mini-screw of higher or lower quality is completely up to the user.

Distribution

A number of mini-screw systems have been in use internationally for several years. Accordingly, there may be a substantial number of users of these products. Perhaps, corresponding reports of experience or clinical research may be available, offering at least a modicum of security when selecting one of those products. In any event, it may be worthwhile to know the actual number of users or devices in use. Unfortunately, some mini-screws may be introduced with minimal prior testing or supporting research. Perhaps skepticism is appropriate, because most clinicians are typically uninterested in being a "test case" or Beta tester. In addition, each orthodontist must also naturally decide if his patients are to be the subject of clinical "experiments" for a new product. To avoid such circumstances, specific minimum requirements should be considered. But with any new device or method, specific problems are often recognized only after extensive application. This is especially true in orthodontics as treatment effects (benefits or consequences) are often evaluated only after a span of at least two to three years. It might be preferable for the clinician to consider those systems that are introduced and distributed only after a significant number of patients have been treated (e.g. 100 patients).

Services

When selecting a mini-screw system, service from the manufacturer is important. For the beginner, introductory and hands-on courses are exceptionally important. Sharing information from experienced users with the possibility of interactive questions is also invaluable. Since many questions often appear during the course of patient care, manufacturers offer an information hotline or support website (i.e. frequently asked questions (FAQs)), which are useful tools as well. Accompanying documentation

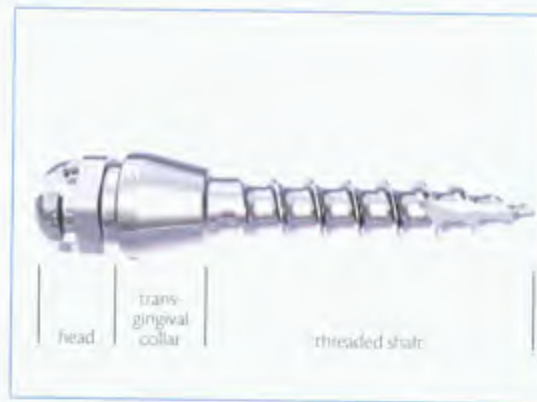


Fig. 3-1 The parts of a mini-screw shown on a tomas®-pin SD 08 (picture: Dentaaurum).

and instructions should provide detailed, clearly illustrated, and easily understood directions for use (e.g. tomas®, AbsoAnchor, Ortho Easy®, and Aarhus-Mini-Implant). For the Dual Top® Anchor-Screw, illustrated instructions are available; however, the accompanying text does not currently provide much information.

Although the insertion of a mini-screw is the foundation of skeletal anchorage, therapeutic effects can only be derived from the applied biomechanics. Clinicians who are interested in adopting skeletal anchorage are often unaware of the multitude of mechanical possibilities. It may be of value to review a selection of documented case reports for examples of similar clinical situations. For example, Park and Kyung's group have published numerous case reports in various journals featuring the AbsoAnchor.

Despite the increased accessibility of scientific journals on the Internet, it can still be a daunting task for a clinician to do a comprehensive literature search. Collections of case reports and research articles offered in a more compact form such as a book or in electronic form (CD-ROM, DVD, Internet) are user-friendly. For instance, Cope has published case studies for the majority of the current mini-screw systems⁷⁵ and there is a comprehensive book available for the AbsoAnchor¹⁰⁰. There is also an illustrated atlas featuring application examples and case studies offered on CD-ROM and on the Internet for both the tomas®-pin and the Ortho Easy® screw.

Some other manufacturers also offer videos to demonstrate the insertion and application of mechanics on CD-ROM, DVD or on the Inter-

net. The quality of these presentations varies significantly, from excellent detail (tomas®-pins) to satisfactory quality (Ortho Easy® screws).

Educating patients about the applicability, procedures, and risks of mini-screws is another extremely important clinical aspect. Patients may be initially apprehensive, especially since the advent of mini-screws is relatively new and foreign to them. As such, they must have enough information to make an informed consent for the use of mini-screws (an important issue of liability). Providing case examples (in the form of pamphlets, brochures, reprinted articles, or CD-ROMs), typodont models, and demonstration videos help to facilitate this process. As mini-screws become more commonplace in clinical practice, more of these types of educational materials will undoubtedly become available. In addition, as more patients are treated using mini-screws, they will become another source for disseminating information and their experiences to other potential patients.

3.3 Screw Design

To paraphrase Gertrude Stein, "A screw is a screw ...". In other words, is there really a difference if a mini-screw from one particular manufacturer is selected? How do the differences between "models" (e.g. design, length, diameter) affect their properties or performance as skeletal anchorage for orthodontic treatment? These and other questions will be considered in this section.

Mini-screws used as skeletal anchorage have their origin in osseointegrated prosthetic implants. Typically, several properties of prosthetic implants preclude their routine use in orthodontics. For instance, the large dimension and design of the head of the implant are not inherently suitable for direct use in orthodontic applications.

3.3.1 The Screw Program

Manufacturers typically offer several mini-screws of different designs. Most importantly, all of these variations should offer safe, temporary skeletal anchorage with a high rate of success. In order to select a specific mini-screw, there are obviously some important points for consideration.



Fig. 3-2 A sterile package of tomas®-pins. The different colors indicate the different length: yellow = 6 mm, blue = 8 mm and green = 10 mm (picture: Dentaureum).

The various strengths and weaknesses of a system may often be determined only during its application. For example, mini-screws should be packaged unambiguously, so that mistakes during insertion, by the user or their assistants, can be avoided. For instance, Orthodontic Mini Implants require the user to determine the length of the screw using a caliper integrated in the delivery tray⁹⁷. In contrast, the length of different tomas®-pins (Dentaureum) can be easily determined by different-colored caps on the vials holding each screw (Fig. 3-2). If, however, a system has a large number of different screw variations, then color-coding becomes problematic. In any event, accurate selection of a desired screw should be quite evident to the end-user to avoid potential errors during the insertion process.

3.3.1.1 Materials

Since mini-screws are implantable medical products, concerns regarding their biocompatibility are the same as those for prosthetic implants. Consequently, technology for fabrication of those osseointegrated devices has simply been applied to their smaller relatives, the mini-screws.

CoCr-base Alloy

The first attempts at using screws as skeletal anchorage were published by *Gainsforth* and *Highley* in 1945⁹⁷. They used Vitallium screws, as did *Creekmore* and *Eklund*⁹¹. This material is a CoCr-base alloy developed in the USA before the Second World War, for use in casting patterns.

This alloy is biocompatible and is still used today for removable partial dentures. Unfortunately, as an implant material, CoCr-base alloys are not ideal. *Gainsforth* and *Highley* found adverse bone reaction that was presumably responsible for the loss of the screws⁹⁷. In later histological studies, *Gray et al*⁹⁶ found the formation of a layer consisting of connective tissue between the metal surface and the bone. In this animal experiment, the cylindrical Vitallium implants demonstrated no mobility after 28 days of orthodontic load (up to 180g). This apparently positive result was most likely reached because of the short observation period, the animal model selected and the size of the implant.

Today, no current mini-screws are fabricated from a CoCr-base alloy (see Table 3-10).

High-grade Steel

High-grade steel is biocompatible, but it is not recommended for skeletal anchorage applications. As with CoCr-base alloys, a layer of connective tissue grows around the body of the steel implant⁹, resulting in distant osteogenesis. Therefore, the contact area between implant and bone is clearly less than with titanium. In addition, steel also significantly interferes with MRI and CT investigations⁹¹.

Currently, only the Orthodontic Mini Implant (Leone) is fabricated from high-grade steel. There appear to be two explanations for the choice of this material. The high-grade steel employed has a slightly higher Young's modulus of elasticity than titanium alloy (see Table 3-1) and, as a result, there should be less bending or breakage. On the other hand, for parameters

Table 3-1 Selected physical parameters of materials for mini-screws

	Steel AISI 316 L VM Or Implant steel 1.4441	Vitallium CoCrMo alloy	cp titanium Ti 1 (Ti Grade 1)	cp titanium Ti 4 (Ti Grade 4)	Titanium alloy Ti-6Al-4V (Ti Grade 5)
Norm	ISO 5832-1: 1997*	ISO 6871-1: 1994*	ISO 5832-2: 1999**	ISO 5832-2: 1999**	ISO 5832-3: 1996***
Yield strength $R_{p0.2}$ (MPa)	255	616 [†]	Minimum 180		Minimum 830
tensile strength R_m (MPa)	534	855 [†]	Minimum 290		Minimum 900
Young's modulus (GPa)	185	ca. 220	105-110	105-110	100-110
Vickers hardness (HV 10)	141	428 [†]	120-150	200	340
Elongation at break (A_5) %	43.5	4.5 [†]	Minimum 25	Minimum 15	Minimum 8
ISO 5832 Implants for surgery — Metallic materials — * Part 1: Wrought stainless steel ** Part 2: Unalloyed titanium *** Part 3: Wrought titanium 6-aluminium 4-vanadium alloy			* ISO 6871-1:1994, Dental base metal casting alloys Part 1: Cobalt-based alloys Technical Bulletin, Austenal		

that are decisive for mini-screws (e.g. yield strength, tensile strength), these are lower than for titanium alloy. A second rationale for selecting steel would be the low force required for removal of the mini-screw after treatment due to their poor osseointegration potential. Interestingly enough, experience has demonstrated no significant difficulty in removing titanium alloy mini-screws (see section 3.5.6), so this aspect appears inconsequential. Therefore, the potential for a higher rate of premature loss for steel mini-screws may be a more important deciding factor, although no data on the rate of survival are available for the Orthodontic Mini Implant (see Table 3-10). Consequently, there appears to be no compelling evidence for mini-screws to be fabricated from high-grade steel at this time.

Titanium and Titanium-alloys

Pure titanium (synonyms: pure titanium, commercial pure titanium – cp titanium or cp Ti) and the titanium alloy titanium-6-aluminium-4-vanadium (Ti-6Al-4V, TiAl6V4 or Ti6-4, material No. 3.7165 – also named Titanium Grade 5) are the current materials of choice for dental implants, both osseointegrated and mini-screws. The biocompatibility and the formation of a direct contact between the bone and the metal surface have been clearly demonstrated^{75,82,83,101}.

As a result, all current mini-screws, except the Orthodontic Mini Implant of Leone (see above), are made of these materials. In compar-

ison with pure titanium, titanium alloy offers more favorable mechanical properties in terms of strength, stress-strain behavior, wear-resistance and surface condition (Table 3-1). The yield strength of titanium alloy is several times greater than pure titanium. Filigree structures like the turn of the threads can be worked-out solidly. Due to the high loading capacity⁷⁵ and the small dimension, all mini-screws, apart from two exceptions, are made of a titanium alloy.

Titanium is often alloyed with aluminum and vanadium. Vanadium has been critically evaluated due to its potential cytotoxicity. Since it is integrated completely into the alloy structure, its safety has been demonstrated in a cytotoxic test series (according to ISO 10993-5, direct contact test and check of extracts). There was no negative effect on cell vitality⁸². Titanium and titanium alloys are also characterized by their corrosion resistance and by their significant biocompatibility. A protective, passivating oxide layer (passive layer) develops on the surface of the metal when in contact with oxygen and tissue fluids. Even in the instance of mechanical damage, the superficial corrosion barrier (passive layer) regenerates within milliseconds due to its affinity to oxygen and nitrogen.

The first generation of the Spider Screw® (HDC) was made of pure titanium¹⁰². Under unfavorable circumstances during insertion or removal of this mini-screw there appears to be a higher danger of fracture^{123,130}.

In an animal experimental study, *Schliephake et al.*¹⁰⁶ discovered that during insertion, particles split-off from the titanium screws, contaminating the bone. After five months, no additional particles were found but the concentration of titanium in the lung increased. No similar results have yet been published for mini-screws.

Osseointegration

Retention, survival rate, and the functional loading capacity of prosthetic and orthodontic implants (including mini-screws) depend on a contact between the bone and the implant material. The formation of such an osseous/implant interface depends on the implant material, the design, the surface structure and a "gingival seal" on the transgingival part of the screw. Biocompatible and biofunctional materials for endosseous implants are titanium Ti6AL4V polymers, carboniferous materials, aluminum oxide, bioglass, hydroxyapatite (HA) and tricalciumphosphate (TCP)-ceramics.^{106,107,108}

Immediately after insertion, the initial retention of any mini-screw or prosthetic implant is purely mechanical in nature, achieved through a combination of displacement and compression of bone. This process, known as primary stability, is independent of the implant material, but highly dependent on the screw design and insertion method or technique^{79,85}. During the insertion of the mini-screw, an osseous wound develops, followed by a corresponding tissue reaction (i.e. hematoma, local inflammation, reparative processes, remodeling processes, and, finally, healing). As a result, the mechanical properties of the bone adjacent to the implant change after the insertion⁷⁹. From the field of implantology, we know that soon after insertion of an implant the contacting thin layer of bone becomes necrotic⁹³. Any voids between implant and bone fill with blood, forming a hematoma, where proteins, lipids and other biomolecules sticking to the metal surface will soon be absorbed. After one week, osteoclasts and osteoblasts become active⁹⁶. Bone that was responsible for primary stability, necrotic bone⁹³, and the hematoma are substituted over different intermediate stages (e.g. granulation tissue) by quickly growing fibrous bone.

During the following 4 to 6 weeks, this simple bone structure is remodeled and reabsorbed. This is a critical phase for implant retention because the contact between originally solid bone and implant surface is temporarily and (presumably) locally lost, but subsequently replaced⁹³. Newly differentiated osteoblasts will form fibrous bone and lamellar bone around the screw, leading to secondary stability. This process depends on the implant material, but also on the surface structure and treatment (i.e. smooth or rough) of the implant or the mini-screw⁹⁶. Titanium has a surface oxide layer to which a non-fibrillar and amorphous zone of glycoproteins and proteoglycans will be added. This provides points of fixation for osteoblasts, osteoids and mineralized matrix at the oxide layer. The process will be concluded by the deposition of mineralized osseous matrix, leading from the wound surface to the implant surface. Secondly, new bone grows at the implant surface itself and extends towards the existing bone^{93,109}. The amount of osseous contact varies during the healing period¹⁰⁶ and reaches the maximum three to six weeks after implant insertion⁹³.

For mini-screws, these processes have not yet been examined in detail, yet it would seem reasonable to assume that they will occur in a similar manner. During the healing phase and functional period, the influence of orthodontic forces on the continuous remodeling and adaptation processes in the bone⁹³ must be taken into consideration. The histologic studies of *Böhm and Fuhrmann*⁹³, *Büchter et al.*¹⁰⁷, *Melsen and Costa*¹¹¹, *Präger et al.*¹⁴¹ as well as *Ohmae et al.*¹⁴¹ demonstrated direct contact between bone and mini-screw.

*Brånemark et al.*⁹³ coined the term "osseointegration" for the acceptance of an alloplastic material by the bone. *Brånemark* (1985) and *Albrektsson* (1981) described osseointegration as "an immediate functional and structural connection between living osseous tissue and the surface of an implant in function"^{93,98}. Over the years, osseointegration has been defined differently but all interpretations appear to have in common the concept of an inanimate metallic structure anchored under functional load in living osseous tissue⁹⁸. In 1986, *Carlsson et al.*⁹⁸ defined osseointegration as a "direct contact between bone and implant without a layer of soft tissue lying between". *Steinemann et al.*¹⁰⁹ defined osseointegration (1989) as "osseous fixation with

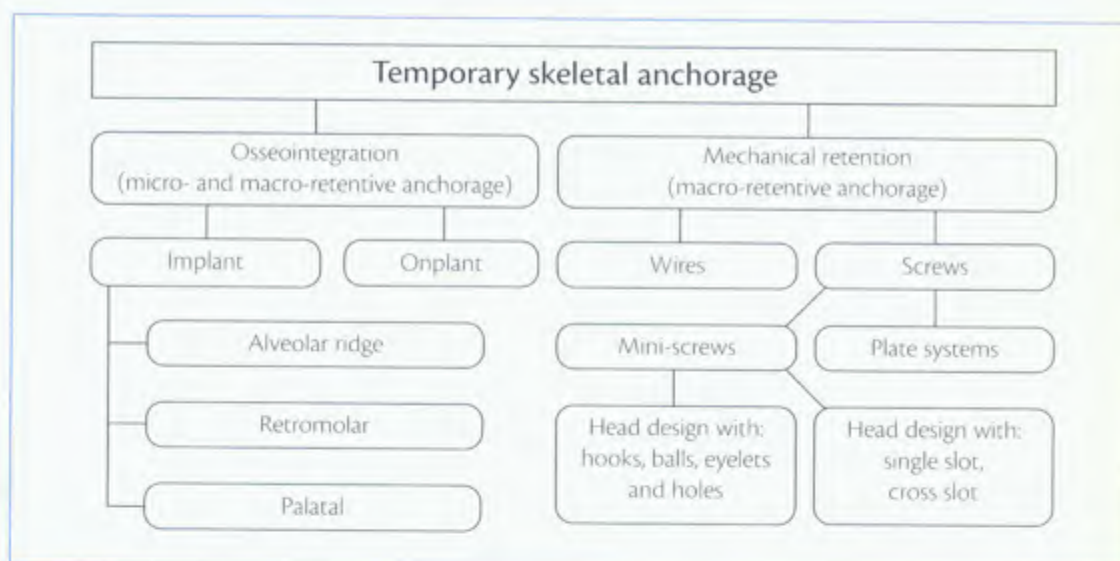


Fig. 3-3 The classification of temporary anchorage devices (TAD) from Cope and Bumann²⁶.

resistance against forces of shear and traction". Zarb and Albrektsson¹⁷⁹ gave a functionally oriented definition in 1991, by describing osseointegration as a process by which an extraneous material can be maintained under a functional load inside bone.

Today, the term osseointegration is not only used to define the process of osseous fixation on a metal surface, resulting in retention of an implant, but is often used as a description of a long-term successful implantation^{35,75}. The fixation of bone to a mini-screw is a process that is obviously influenced by many factors. For example, the influence of healthy surrounding soft and hard tissue cannot be discounted. Inflammation (e.g. caused by microorganisms) can adversely affect the bone/implant interface. Therefore, good adaptation of healthy gingiva to the transgingival part of the mini-screw is very important⁷⁵.

The anchorage of mini-screws in bone or the apposition of bone on the surface of the mini-screw is referred to as osseointegration by many authors^{12,15,19,20,36,47,87,107,111,112,113}, especially in those reports featuring histological investigations. Unfortunately, none of these articles adequately define or describe osseointegration. Considering the large number of definitions and interpretations, the use of the term might be somewhat confusing.

Costa stated that "osseointegration is subject to the level of loading and it is not the aim of implant (mini-screw) anchorage"⁸⁸. Maino et al¹⁰⁷ also concluded: the effectiveness of a mini-screw as anchorage is not dependent on os-

seointegration. According to Cope³⁴ and Bumann et al²⁴, mini-screws are anchored primarily by mechanical stabilization and not by osseointegration. As a result, they have suggested that temporary skeletal anchorages (temporary anchorage devices – TADs; see Fig. 3-3) be divided into two different categories depending on the type of anchorage that is derived in the bone: TADs with osseointegration (e.g. orthodontic implants, flat screws) and those based on primarily mechanical anchorage (e.g. wires, plate systems, mini-screws).

Whatever the anchorage may be called or how the devices are categorized, the fact is that there is direct contact between bones and the mini-screws (bone/implant interface), whether they are made of titanium or titanium alloys. No layer of connective tissue was found between the bone and mini-screw in any investigation^{6,8,15,19,20,36,46,47,111,112,131}. This interface is based on the passive layer of titanium (titanium oxide) and is, therefore, specific to the material used to fabricate the mini-screw. In addition, the form of the body – implant or mini-screw – plays a subordinate role. As previously described, this direct contact between screw and bone, critical for clinical success, does not appear to occur with other biocompatible metals or alloys.

So, does osseointegration occur with mini-screws? It depends upon the definition. If osseointegration is defined as safe and stable retention of a mini-screw, and therapeutic safety linked with it, then the answer would be a resounding "yes". If, however, the concern is

that the mini-screw cannot be subsequently removed as a result of osseointegration, the answer would be "no". Clinical experience has demonstrated that mini-screws used for skeletal anchorage have a high rate of success and, yet, can still be easily removed.

Surface

The type of material used to fabricate an implant determines the nature of the direct contact between implant or mini-screw and the bone. Because the bone and soft tissues only contact the metal, the surface (including any coating) is the specific determinate for the quality of that contact. When implants were first introduced, their surfaces were initially polished smooth. Later, they were roughened (e.g. sandblasted, etched) to increase the contact surface area between bone and implant surface^{99,107,181,95,92,112,113}.

The thickness of the titanium oxide layer directly influences the stability of implants in bone^{102, 89}. Mini-screws that do not have the typical silver-grey appearance of the oxidized layer (e.g. Aarhus-Mini-Implant, Anchotek screw, Ortho Easy®, Orthoanchor, LOMAS screw) have been anodized. During anodization, an oxide layer of different thickness is produced, often of a different color. It has been reported that the thickness of this anodized layer may provide improved retention of the implant (e.g. osteosynthesis-screws)¹⁰¹. Unfortunately, the exact benefit from this process has not been specifically documented for mini-screws, and considering the many other parameters involved in stability of a mini-screw, it may be difficult to demonstrate definitively.

A greater degree of bone/implant contact is desired for prosthetic implants since permanent anchorage is the goal. It is for this reason that endosseous implants were roughened and coated with materials such as hydroxyapatite (HA) or tricalciumphosphate (TCP)^{64,112}. Anchorage with mini-screws, on the other hand, is intended for a limited working period; however, retention must be able to support the forces of orthodontic mechanics. In addition, at the end of treatment, the mini-screw should be easy to remove. As a consequence, mini-screws typically have polished threads. This results in a tenfold lower contact area between screw and bone compared to the rough surfaces of prosthetic implants^{118,98,107,110}, as monocytes do not adhere as well to smoother surfaces¹⁶⁹.

The surface roughness of grade 5 titanium does appear to influence the activity of osteoblasts during the first hours immediately after insertion⁹¹. Experiments with coated implants have demonstrated accelerated bone adhesion to the surface of the implant. This is not necessary for mini-screws as they can be loaded immediately after insertion (See section 3.5.3). A polished or smoothly milled surface offers a reduced contact surface area for bone that also affects secondary stability^{96,157} and reduces the resistance for removal of the mini-screw. As a result, more attention must be paid to the method of mini-screw insertion along with the quality and quantity of bone at the implant site for favorable stability⁹⁶.

In conclusion, orthodontic implants (e.g. palatal implants) have a rough surface and are stabilized by both macro- and micro-retentive anchorage. Mini-screws, with their smooth threads, are stabilized almost entirely by macro-retentive anchorage. The smooth and small surface area of mini-screw threads is an advantage for easy removal at the end of TAD-based mechanics.

Design

Currently, all mini-screws in the marketplace are one-piece in design. Caution should be exercised if a mini-screw is introduced that consists of multiple parts as the junction of the components may be a mechanical weak point. If, in addition, the parts are fabricated from different materials, this may lead to a higher rate of corrosion.

3.3.1.2 Size and Number of Mini-screws

The numerous publications describing the use of mini-screws within the scope of orthodontic therapy clearly show the varied possibilities of this form of skeletal anchorage¹³⁷. Due to their small size (diameter and length of the threaded shaft), mini-screws can be readily inserted between the roots of teeth. This is a substantial advantage over endosseous implants or mini-plates.

Consequently, only a few different lengths of screws are likely to be needed for most typical applications. Maintaining an inventory or even producing a mini-screw system with more than ten different screws seems redundant and unnecessary.

Diameter of Mini-screws

The typical diameters of available mini-screws vary between 1.2 mm and 2.3 mm, a measurement that normally refers to the external diameter. Since the diameter is often the deciding factor when choosing a mini-screw for a specific application, it is important to note that there is no regulation ensuring that manufacturers are actually referring to external diameter when listing that dimension in marketing materials. If there is any doubt, then the manufacturer should be asked.

Safe and stable mini-screw anchorage requires a certain amount of bone around the device. Interestingly enough, recommendations for minimal amounts of bone vary substantially in the literature, such as 0.5 mm^{16,107}, 1 mm^{108,109}, 1.5 mm¹¹⁰ and 2 mm¹¹¹. An expectation for more than 1.5 mm of bone around a mini-screw is unrealistic and unlikely when the device is placed between roots. Unfortunately, there is no study or consensus as to the minimal amount of bone required. Obviously, if mini-screws are inserted in an edentulous region (e.g. retromolar region or hard palate), then sufficient osseous support exists for larger diameter screws.

Since mini-screws are most often placed between roots, the amount of inter-radicular space is crucial in determining the insertion site¹¹² and the maximum diameter of the screw. The position of the teeth, the diameter of their roots, and the distance between them determine the amount of inter-radicular bone available at the point of insertion. During orthodontics, tooth position changes and, as a result, inter-radicular space and even the size of the apical base will vary over time. Some of these changes should be considered when selecting an implant insertion site.

When placing mini-screws, we intend to avoid periodontal injury and infection. As a result, the design and dimensions of the head and transgingival portion of the screw must be considered when selecting an insertion site. Fewer soft tissue complications have been reported when the mini-screw is inserted within the attached gingiva^{103,113,114}. In most cases, it would be preferable to place mini-screws occlusal to (or below) the mucogingival line in the maxilla and occlusal to (or above) the mucogingival line in the mandible. Considering the constraints of the area of attached gingiva (and underlying bone), there are some substantial limits for ide-

al available space for mini-screw placement. Poggio et al¹¹⁵, Schnelle et al¹¹⁶ and Costa et al^{114,117} examined the relationship between the cemento-enamel junction and the mucogingival line. These investigators concluded that the maximum diameter of an inter-radicular mini-screw should not be larger than 1.6 mm. In fact, Poggio et al¹¹⁸, Sung et al¹¹⁹ as well as Park et al¹²⁰ have recommended that the ideal diameter should be from 1.2 to 1.5 mm.

Although selecting the appropriate external diameter of a mini-screw is important, the mechanical properties must also be considered. The load on the screw during the insertion, its functional period and during its subsequent removal also play a role. Mini-screws made from titanium alloy TiAl6V4 clearly permit fabrication of a smaller size mini-screw compared to those made from pure titanium⁷³. Screws with a diameter of less than 1.4 mm for self-tapping and of 1.5 mm for self-drilling may not reliably withstand these loads¹⁰⁶ and could potentially bend or break^{111,116}. Park et al¹²¹ reported that 7 of 157 AbsoAnchor screws exhibited breakage during insertion or removal. Büchter et al¹²² also described bending and fracture of the AbsoAnchor (diameter 1.1 mm, length 10 mm) and the Dual Top® Anchor-Screw (diameter 1.6 mm, length 10 mm). Fracture of the Dual Top® Anchor-Screw was also noted by Wilmes et al¹²³. As a consequence, fracture must be considered a risk for any mini-screw.

The diameter appears to play an important role in the success rate of mini-screws^{84,124}. For instance, Miyawaki et al¹²⁵ found that all screws with a diameter of 1 mm were lost prematurely, whereas those screws with a diameter of 1.5 mm or more had an 85% success rate. There also seems to be no significant difference in rate of loss for mini-screws with a diameter between 1.3 mm and 2 mm¹²⁶. It may be concluded that much of the stability and success of mini-screws is due to their diameter and not their length^{88,127}.

Mondeal's LOMAS system offers an "emergency" or "rescue" screw with a diameter of 2.3 mm. They recommend that if a typical LOMAS-screw (diameter 1.5 mm or 2.0 mm) is lost prematurely, then this rescue screw can be inserted into the same hole that the failed screw just vacated. The larger diameter screw will theoretically provide better anchorage in that same site. Does this function in practice? As was previously discussed, Poggio et al¹²⁸ rec-

ommended that a minimum of 0.5 mm of bone surround the mini-screw. Therefore, a minimum of 3.3 mm of inter-radicular space would be required for the rescue screw, an amount that is unlikely to be found in the maxillary dental arch, but is theoretically possible in some spots in the mandibular arch. Even if sufficient bone is available for the rescue screw, what is the status of the bone and soft tissue in the location of the previously failed implant? It does not appear rational to place another screw, even if larger in diameter, into a site that exhibits active inflammation usually accompanying premature loss. It seems more prudent to select a new location where a mini-screw of appropriate diameter may be inserted.

The optimal diameter for a mini-screw is a compromise among the demands of the application (the selected type and location of the biomechanics), the amount and quality of bone, and the properties of material used for screw fabrication. When all aspects are considered, mini-screws (titanium grade 5) with a diameter of 1.5 mm or 1.6 mm are those that are recommended.

Length of the Mini-screw

The lengths of currently available mini-screws vary between 4 mm and 15 mm. Although this dimension normally refers to the length of the threaded shaft, some manufacturers reference the total length of the screw (i.e. shaft, transmucosal collar, and head). Just as when selecting the diameter of a mini-screw, the appropriate length is also dependent upon the amount of bone available. Depending on the region of bone in the dental arch, the total thickness available typically ranges between 4 mm and 16 mm¹⁰. Screws that are longer than 10 mm could result in greater risk of iatrogenic perforation (i.e. on the lingual side of the mandible or into the maxillary sinus)¹¹.

It might be intuitive that the longer the mini-screw, the better the retention and distribution of forces. In actuality, the length of the mini-screw is of secondary importance; the thickness of the cortical plate through which the implant is inserted is a more critical factor. The thicker the cortical plate^{116,178,179}, the more reliable the anchorage. It has been reported that greater retention also results if a mini-screw is inserted at an angle to the cortical plate as this

increases the surface contact between the screw and the cortical bone¹¹⁵. In FEM analyses of the distribution of forces along the length of a mini-screw, the majority of the load is borne within the cortical bone¹⁴².

The thickness of soft tissue is also a factor in deciding on an appropriate mini-screw length^{119,180}. A 1:1 ratio of the length of the head of a mini-screw (portion outside the bone) to the threaded shaft (portion held within the bone) is preferred. Soft tissue in the posterior hard palate and in the mandibular retromolar region may have a thickness of 4 mm. Since the mini-screw should be anchored by 4 mm of bone, then a mini-screw with at least an 8 mm threaded shaft would be required.

The mechanical properties of materials used to fabricate the mini-screw become more important with longer screws. A longer screw with a small diameter may be more subject to bending or breakage. The length of a screw should be inversely proportional to the diameter¹⁸. It would seem that longer screws should also have a larger diameter. The AbsoAnchor system offers 12 mm screws with a diameter of 1.2 mm⁹¹. Caution may be warranted when considering screws with these dimensions due to limitations in material strength. Poggio et al¹⁸ recommended mini-screw lengths between 6 mm and 8 mm. For Costa¹⁸⁴⁰, mini-screws with a length between 6 mm and 10 mm are acceptable.

Perhaps for most clinical applications, longer screws are unnecessary. An inventory of mini-screws of 6 mm, 7 mm, 8 mm, 9 mm and 10 mm lengths could be maintained but there are likely to be minimal differences in the rate of success between mini-screws that are only 1 mm different in length. As a result, it may be more economical and less confusing to simply keep a selection of screws at 2 mm gradations (e.g. 6 mm, 8 mm, and 10 mm lengths).

When selecting a mini-screw of a specific length, the amount of available bone (≥ 6 mm), the thickness of the gingiva and the height of the head of the screw play important roles. The portion of the mini-screw that is within the bone must be at least as long as the part outside the bone. It would seem from the previous discussion that mini-screws of 6 mm would be used primarily in the mandible, 8 mm for either maxilla or mandibular applications, and 10 mm in the maxilla or perhaps in instances where bicortical anchorage is required or in retromolar areas of the mandible.

Table 3-2 The number of mini-screws in the delivery program of different companies (July 2006)

Mini-screw name	Company	Number of mini-screws *			
		Diameter	Length	Design variants	Total
Aarhus-Mini-Implant	Medicon, Germany	3	11	4	11
AbsoAnchor	Dentos, Korea	7	6	7	154
Anchor Plus / NeoAnchor Plus	Myungsung, Korea	2	5	2	40
Ancotek	Tekka, France	3	4	22	70
Dual-Top Anchor Screw	Jeil Medical Corp., Korea	3	3	5	40
LOMAS	Mondeal, Germany	3	5	3	44
MTAC	American Orthodontics, USA	2	2	1	4
O.A.S.I.	Lancer Orthodontics, USA	1	3	2	6
Orlus	Ortholution, Korea	2	8	7	11
Ortho Anchor Screw	KLS Martin, Germany	1	2	1	2
Ortho Easy®	Forestadent, Germany	1	2	1	2
Ortho Implant	IMTEC Corp., USA	1	3	1	3
Orthoanchor	Dentsply-Sankin, Japan	1	3	1	3
Orthodontic Mini Implants	Leone, Italy	2	4	5	18
Orthodontic Mini-Implant	Bio Materials Korea, Korea	9	9	4	19
Spider Screw	HDC, Italy	2	6	7	21
tomas®-pin	Dentaurum, Germany	1	3	2	6

* Screws that are available as sterile and non-sterile were counted only once

Number of Screws

It appears that only three different screws are necessary for most clinical applications. An inventory of 1.6 mm diameter mini-screws of 6 mm, 8 mm, and 10 mm lengths all of one head design can be used for both indirect and direct anchorage applications (see section 3.3.2). Interestingly enough, individual vendors offer anywhere from 2 to 154 different variations (e.g. thread, transgingival and head differences; Table 3-2).

Only two manufacturers have reported which screws are most often inserted. *Ahnfeldt*³ reports that of the 40 different variations of the Dual Top® Anchor-Screw, screws of only two different lengths and two diameters are used 70% of the time. In other words, 10% of the Dual Top® Anchor-Screw options can satisfy two-thirds of all clinical applications. The Dentos Company brochure (4th edition, Jan. 2006) lists 31 of 154 types of AbsoAnchor as the most popular⁹³. With increasing mini-screw use, similar distributions from other companies will

likely emerge. It seems clear that only a small number of different mini-screws will need to be maintained in a clinical inventory to satisfy most clinical applications.

A large number of screw variations complicate the selection process, increase the risk of miscommunication and mistakes, and increase inventory and associated costs. Introductory kits for many screw systems include an unnecessarily large number of different screws. In the course of time, only a small selection will be required so that the rest are redundant and a monetary waste. A large number of mini-screw options may convey the impression of greater competence, as there appears to be a solution for all imaginable applications; however, the opposite is true ...

Only a few screws of ideal design, easy to handle, and with a low risk potential for patient and practitioner will likely serve the vast majority of clinical applications.

Mini-screw name	Head design				
	Hook	Ball	Eyelet / hole	Single slot	Cross slot
Aarhus-Mini-Implant		x			x
AbsoAnchor		x	x	x	
Anchor Plus/NeoAnchor Plus			x		
Ancotek		x			x
Dual-Top Anchor Screw		x	x	x	x
LOMAS	x			x	x
MTAC			x		
O.A.S.I.			x		
Orlus			x		
Ortho Anchor Screw			x		
Ortho Easy*					x
Ortho Implant			x		
Orthoanchor			x		
Orthodontic Mini Implants			x		
Orthodontic Mini-Implant	x		x	x	
Spider Screw					x
tomas*-pin					x

Table 3-3 The different head designs

3.3.2 The Screw Head

The "head" is often considered the most important aspect of mini-screws. Although it is important to select the appropriate length and diameter, the head design must be applicable to a particular clinical situation. Different elements of the orthodontic mechanism (e.g. elastic chain, coil springs, auxiliaries, sectional and continuous arch wires, etc.) must be attached to the head of the screw (Table 3-3). Currently, the following five types of head design are available:

- screw with hook (Fig. 3-4a)
- screw with ball head (Fig. 3-4b)
- screw with hole through the head (Fig. 3-4c)
- screw with a simple slot (Fig. 3-4d)
- screw with cross-slot (Fig. 3-4e)

Combinations among these designs are also available, for example, the MTAC has two holes drilled through the head and the Spider Screw features a cross-slot coupled with an additional hole drilled through the head.

Many companies also offer screw systems with up to eight different heads, like the AbsoAnchor (8 heads), Dual Top® Anchor-Screw (4 heads), the LOMAS screw (3 heads), and the Orthodontic Mini-Implant (3 heads). At first glance, having many variations may seem to be an advantage as a head design can be selected from inventory for each specific application. In actuality, it may be a disadvantage. If, for instance, a change in treatment plan or mechanics is required during the course of treatment, then it might be more beneficial to have placed a mini-screw with some type of universal head design. A screw with a hook would be ideal when elastic chain or coil spring is to be used. Unfortunately, when a rectangular wire segment is required for indirect anchorage later in treatment, there may be no simple way of applying these mechanics, and replacement with a cross-slot or bracket head screw would be necessary. This is not an economically practical solution, nor is it likely to be acceptable to the patient.



Fig. 3-4 Different head designs.

Fig. 3-4a Screw with hook, LOMAS-hook-screw (picture: Mondeal).

Fig. 3-4b Screw with ball head, e.g. Dual Top® Anchor-Screw JB (picture: Jeil Medical Corp./Promedia).

Fig. 3-4c Screws with eyelets or holes, e.g. T.I.T.A.N. flat head and one hole (picture: Forestadent).

Fig. 3-4d Screw with single slot, e.g. Dual Top® Anchor-Screw JD (picture: Jeil Medical Corp./Promedia).

Fig. 3-4e Screw with cross-slot, e.g. tomas®-pin (picture: Dentaaurum).

It appears that one head design that could be used for nearly all clinical applications would be ideal. This design should permit the simple addition of all types of auxiliaries (e.g. springs, elastic chains, round wires, square wires) and the simple application of direct and indirect anchorage.

The advantages and disadvantages of different contemporary head designs are described below.

Screws with Hooks

Indications: primarily mesial and distal translation, with restrictions: space closure and intrusion.

Coupling elements: elastic chains, tension or coil springs, round wires.

Advantages: most coupling elements can be easily applied.

Disadvantages: during screw insertion, the correct orientation of the hook to retain the coupling element must be considered. For instance, this problem may arise with the LOMAS screw (with a hook) as it is inserted (see chapter 3.3.3 - Relation of Transgingival Part to the Screw Head). If a tissue punch is used, there is a step functioning as a depth stop between the threaded shaft and the transgingival collar. If the screw is inserted up to this stop, but the hook is incorrectly oriented, there are two possible solutions. Either the implant can be unscrewed to the correct orientation for the hook or further tightening of the screw could be attempted. This could

result in “stripping” or auguring of the bone and poor primary stability. Bending or breakage of the screw could also result from this additional tightening. If no tissue punch is utilized and the orientation of the hook must be altered, then additional tightening will compress the gingival tissue (possibly leading to inflammation and tissue overgrowth) and unscrewing will produce a gap between the collar and the soft tissue that may be difficult to keep clean. Obviously, both variations are unfavorable. Another disadvantage is that the hook could be bent or broken. In this instance, the entire screw must be replaced.

Screws with Ball or “Triangular” Heads

Indications: primarily mesial and distal translation, with restrictions; space closure and intrusion.

Coupling elements: elastic chains, tension or coil springs, round wires.

Advantages: most coupling elements can be easily applied. Orientation of a ball head, in contrast to screws with hooks, is not necessary.

Disadvantages: the connection between the ball (or triangle) and the screw body is the only purchase point for applying orthodontic forces. This provides for very limited application, as indirect anchorage is not easily achievable with this type of mini-screw. The dimension of the neck portion could also be a weak point and a potential site for fracture (especially if a hole is drilled into that portion of the head). Should this occur then the screw must be replaced.

Screws with Eyelets or Holes

Indications: primarily mesial and distal translation, space closure, and intrusion.

Coupling elements: round wires, tension springs, elastic chains.

Advantages: although this is the most common type of mini-screw head, there appears to be no advantage compared to those with either a hook or ball head.

Disadvantages: the holes are drilled into nearly any shape of mini-screw head (e.g. mushroom head, cone, cylinder, etc.). Independent of head design involved, there is a basic disadvantage if either round or square wires are used: the coupling mechanism must be threaded simply through the hole or eyelet. Depending upon the insertion site of the implants, the diameter of the hole and its orientation (vertical, horizontal, or diagonal), it may be difficult to thread the wire through that hole. This becomes more problematic the more posterior that the mini-screw has been placed and how close the hole is to the soft tissue. Only the original MTAC screw offered two holes that were drilled parallel to each other.

The diameter of the hole determines the maximum diameter of wire that can be inserted. If, however, a larger diameter hole is drilled in a head that is of a small dimension, the strength of the supporting material could be compromised (Fig. 3-5) and could result in fracture, requiring replacement.

Screws with a Single Slot

Indication: uprighting, intrusion, extrusion, mesial and distal translation, and much more.

Coupling elements: square and rectangular wires, round wires, tension springs, elastic chains.

Advantages: square or rectangular wires can be used.

Disadvantages: depending on the intended purpose of the mini-screw, the slot must be oriented vertically or horizontally during insertion. This may be more difficult for screws that have a single slot (AbsoAnchor, Dual Top®, LOMAS screw). As described previously, correct orientation varies by 90° so that the screw may have to be inserted just short of its maximum depth or would require additional tightening to orient the slot (previously described in "Screws with Hooks"). As an alternative, some wires can certainly be bent to account for the incorrect orientation of the slot.



Fig. 3-5 The head of AbsoAnchor small head (SH) type is very small. The wall thickness around the eyelet is very low. This could be a predetermined possible breaking point (photo: OA Dr. B. Wilmes, University of Düsseldorf).

Screws with a Cross-slot

Indication: uprighting, intrusion, extrusion, mesial and distal translation, and much more.

Coupling elements: square and rectangular wires, round wires, tension springs, elastic chains.

Advantages: this appears to be the best of both worlds. The cross-slot has all of the advantages of the previous head types¹⁰⁸. The head design has the added advantage of permitting the incorporation of square or rectangular wire segments for indirect anchorage applications that open new horizons in biomechanics for advanced users of mini-screws. Round wires typically permit only one-dimensional control, whereas three-dimensional control of tooth movement or anchorage control is possible with square or rectangular wire^{109,110}.

While previously described head variations only cover two-thirds of the typical applications for mini-screw anchorage¹¹¹, mini-screws with a cross-slot permit the addition of a wider variety of coupling elements, thereby increasing the number of clinical applications. Screws that feature slot widths of 0.56 mm (0.022") include: tomas®-pin; Ortho Easy®; Aarhus-Mini-Implant (System 1.6 and 1.3); Ancotek (Bracket head and Cross-Fit head); Dual Top (G1 and G2); and LOMAS Quattro. This slot size permits the use of the most common dimensions of orthodontic wire. Interestingly enough, the Spider Screw® has a cross-slot with a dimension of 0.53 mm x 0.63 mm (0.021 x 0.025") and also has an additional 0.63 mm (0.025") diameter hole¹⁰⁷.

Orientation of a cross-slot during insertion is much easier than head designs with only a simple slot, as no more than a one-quarter turn or 45° variation is necessary to orient one of the slots to the desired position.



Fig. 3-6 Aarhus Mini-Implant: System 1.6 (a) and one-point-head 1.6 (b) with head diameter of 3 mm.



Fig. 3-7 Head of the tomas®-pin with 22 cross-slot and maximal slot depth of 1.1 mm. The midline of the slot is marked on the transgingival collar to properly orient the slot during insertion (picture: Dentaurum).

Disadvantages: There appear to be none.

The Ancotek-screw system offers screws with either a 0.018" or 0.022" slot width. The 0.022" slot width permits a wider variety of wire dimensions to be used but this must be balanced by an accordingly safe fixation (see section 3.5.3.), so having screws with different slot sizes seems redundant.

Some mini-screws appear, at first glance, to have a cross-slot. In actuality, these slots are simply to hold the screwdriver during insertion. As such, these slots are typically too shallow for the application of larger dimension wires.

Dimension

A small diameter and lower profile of the mini-screw head are important for oral hygiene and patient comfort. Obviously, the head must be of sufficient dimension to accept and hold any coupling elements selected for a particular application, and different head designs also require different dimensions. For example, the size of an AbsoAnchor small head (SH) Type (level head with a hole, see Fig. 3-5) cannot be compared with a cross-slot head (Fig. 3-6a and 3-7); it's like comparing apples to oranges, because for the safe stabilization of a wire, a specific slot is necessary. Therefore, a comparison of head dimensions makes sense only within screws of the same type.

Mini-screw and Insertion Instruments

The connection between a mini-screw and its associated insertion instrument or "driver" is critical. A reliable connection is required for

three tasks. First, the screw should not fall-off the driver from the point where it is removed from its sterile packaging and to the point of insertion in the patient. Secondly, torque must be safely transferred from the driver to the screw against the resistance of the bone without wobbling, distortion, or breakage of the screw. Finally, the insertion instrument should also be readily usable as a removal tool.

Most insertion instruments contact only the head of the mini-screw. In contrast, the driver contacts the transgingival collar for some variations of the AbsoAnchor (see section 3.3.3). The contact between screw and driver can be either external or internal. The advantages and disadvantages of these two variations are shown in detail in section 3.4.4. If a mini-screw features a simple slot or a cross-slot, then the orientation of the slots should be readily apparent during insertion. In other words, the slot position should be apparent during placement with the insertion instrument in position (Fig. 3-7).

3.3.3 The Transgingival Collar

The transgingival (also transmucosal) collar or neck is the sensitive part of implants and mini-screws. Any perforation in the soft tissue provides a potential entry point for microorganisms and could give rise to inflammation or infection (perimucositis, peri-implantitis)⁷⁶, often resulting in premature loss of mini-screws^{135, 482}. Inflammation must be avoided to reduce the rate of loss^{28, 404, 111, 117, 120, 135, 136}. Reasons for the development of perimucositis or peri-implantitis are multi-factorial. Immediately after mini-screw

Mini-screw name	Gingival collar			
	Cylindrical	Conical	Hexagonal	Thread
Aarhus-Mini-Implant	x			x
AbsoAnchor	x		x	
Anchor Plus/NeoAnchor Plus				x
Ancotek		x		
Dual-Top Anchor Screw				x
LOMAS			Square	
MTAC				x
O.A.S.I.	x			
Orlus	x			
Ortho Anchor Screw	x			
Ortho Easy*		x		
Ortho Implant				x
Orthoanchor	x			
Orthodontic Mini Implants		x		
Orthodontic Mini-Implant	x			x
Spider Screw		x		
tomas®-pin		x		

Table 3-4 The design of the gingival collar

insertion, the mucosa should provide a seal around the screw²⁴. This necessitates careful management of the tissue during the insertion process (see section 3.5.2) and also depends on the design and the size relationship between the transgingival collar and the head. There is only limited information on the influence of these parameters¹⁵. Certainly, the quality of the patient's oral hygiene and care of the mini-screw also play critical roles.

Design/Dimension

The transgingival part of mini-screws have been produced in four different basic forms: cylindrical, conical, poly-angular (square, hexagonal or octagonal) or, in some instances, the thread continues up to the head and there is no collar or neck (Table 3-4). The soft tissue will typically heal and adapt to each of these forms. Nevertheless, there are some differences dependent upon the nature of the gingival perforation by the screw (see section 3.5.2) and also on the direction of insertion of the mini-screw. For in-

stance, pressure zones can develop, dependent on the angulation of insertion, for screws with a cylindrical neck. A cone-shaped collar reduces the possibility of these adverse pressure zones, especially if a tissue punch is used prior to insertion. If the diameter of the transgingival portion of the mini-screw is slightly larger than that of the hole punch, there is likely to be a closer approximation of the soft tissue to the collar. As a result, a protective seal between tissue and screw may reduce the infiltration of microorganisms and the potential for inflammation. In addition, the cone shape helps to seal the perforation wound, much like a cork seals a bottle, and, thereby, reduces bleeding²⁴.

The transgingival collar of some AbsoAnchor screws is hexagonal because a hexagonal driver contacts this part of the screw. In this system, the neck or collar is completely covered by the inserting device. As a consequence, either the insertion driver will compress the soft tissue during insertion or the screw cannot be completely inserted. Both possibilities are unfavorable.

Table 3-5 The relation of diameter between the gingival collar and the head of the mini-screw

Mini-screw name	Relation of gingival collar (internal) to the head (external)		
	collar < head	collar = head	collar > head
Aarhus-Mini-Implant	x		
AbsoAnchor		x	x
Anchor Plus/NeoAnchor Plus	x		
Ancotek		x	x
Dual-Top Anchor Screw	x		
LOMAS			x
MTAC	x		
O.A.S.I.		x	
Orlus	x		
Ortho Anchor Screw	x		
Ortho Easy*			x
Ortho Implant	x		
Orthoanchor		x	
Orthodontic Mini Implants		x	
Orthodontic Mini-Implant	x		x
Spider Screw			x
tomas®-pin			x

In an FEM analysis, *Gedrange et al*⁶¹ reported that orthodontic implants featuring a suprapariosteal collar demonstrate better load distribution of the bone. The tomas®-pin has such a collar that also serves as a depth stop. The diameter of transgingival collars and threaded shaft are identical for most mini-screws.

The typical thickness of the gingiva (according to *Goasland et al*⁶²) is, on average, about 1.25 mm. *Costa et al*⁶³ reported the typical thickness is from 1.4 mm to 4.2 mm, depending upon the region where it is measured. Depending upon the location in the mouth and the patient's gender, *Müller et al*¹⁷⁰ described gingival thickness between 0.7 mm and 4 mm. The length of the transgingival collar for most mini-screws varies between 1 mm and 3 mm; this satisfies *Mampieri's*¹⁰⁸ recommendations to traverse the typical thickness of gingival tissue for most applications. However, before the insertion of a mini-screw, the thickness of the gingiva should be measured.

The most popular locations for mini-screw insertion are between the maxillary first molars and second premolars and also between the mandibular first and second premolars. The average gingival thickness in those areas is about 1–2 mm. It may seem that mini-screws with different transgingival collar lengths would make sense; however, this would require a larger inventory. Furthermore, the gingival thickness can be measured only after anesthesia, just prior to insertion. As a result, the selection of the mini-screw would have to be delayed until the instant prior to its placement. A transgingival collar of 2 mm is sufficient to traverse the gingiva and produce a safe seal against the neck in most, although collars less than 1 mm would be insufficient in some locations and more than 3 mm is unnecessary. Even if the thickness of gingiva is greater than 2 mm, longer variations are not necessary as long as there is close adaptation of the gingiva on the collar's surface. The areas of gingiva next to the bone are of lesser importance.

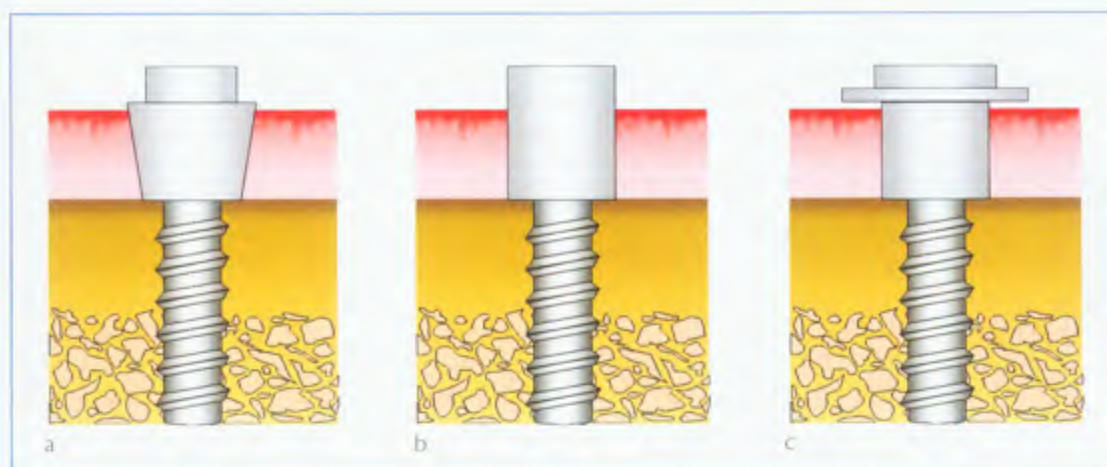


Fig. 3-8 The diameter of the transgingival collar in relation to the diameter of the head. To avoid inflammation around the screw (perimucositis), it is recommended that the diameter of the head should be smaller than (a) or equal to (b) the diameter of the head. The gingiva around the screw is difficult to clean if the gingiva is covered by part of the mini-screw (c).

Some mini-screws do not have a transgingival collar or neck as the screw threads terminate directly at the head. Typically, the head has a larger diameter than the threaded portion. This may exhibit some disadvantages, as described below.

Relationship between the Transgingival Collar and the Screw Head

There are three possibilities for diameter differences between the head (outside) and transgingival collar (inside) of a mini-screw: collar < head; collar = head; collar > head (Table 3-5, Fig. 3-8). If the screw head (like a pan or button head screw) has a larger diameter than the transgingival part, niches between the head and the soft tissue may harbor debris and microorganisms and may be difficult to keep clean. If mini-screws with a plate-shape, pan or button head (i.e. the head diameter is wider than the threaded shaft) (Fig. 3-8c) are not inserted perpendicular to the soft tissue, a portion of the head may be embedded into the gingival tissue while the opposite side may demonstrate a gap. Either circumstance may result in a higher rate of inflammation (perimucositis/peri-implantitis) and possible premature loss^{15,147,150}. Plate-shaped heads are found with the Dual Top® screw (JA, G2 and JD), the OSAS screw and the MTAC screw with collar and hole (see Fig. 3-4c).

To reduce these risks and to make it easier for the patient, it appears that the diameter of the head should be the same or smaller than the diameter of the neck or collar (Fig. 3-8a and 3-8b). Perhaps less inflammation and loss will result^{171,172}.

The LOMAS screw (see Fig. 3-9) has a somewhat unique transgingival collar. Depending



Fig. 3-9 The LOMAS screw offers two techniques for insertion. In one of these, the screwdriver extends over the transgingival collar. Due to this, the gingiva will inevitably be bruised during insertion (picture: Mondeal)

upon the insertion procedure, it is located at a different point on the screw. If the screw is inserted directly through the gingiva, then the wider part of the head (actually the collar) lies directly on the soft tissue; potentially a disadvantage as previously discussed. If, however, a tissue punch is used, then the LOMAS screw is inserted until the "head" contacts the bone. The area where the insertion driver contacts the screw is at both the head and transgingival portion. Therefore, the driver completely covers the transgingival part of the screw and may damage the tissue during the insertion process. In this circumstance, the "head" is actually smaller in diameter than the "neck".

Surface

Somewhat like bone, titanium appears to be biocompatible with soft tissue. In addition, the gingiva forms a seal around the screw that helps to prevent the penetration of microorganisms⁶.

It does not seem to matter whether the transgingival collar is rough or polished. There appeared to be no difference in proliferation of fibroblasts and the metabolism of the cells after 48 hours for LOMAS screws with different structural surfaces¹⁵¹. There was also no difference with regard to plaque accumulation and inflammation for rough or smooth implant abutments^{152,153}. A smooth surface, however, seems to permit a more favorable soft tissue “seal” at the time of implant penetration; thereby helping to prevent perimucositis and peri-implantitis¹⁵⁴.

3.3.4 Shank and Thread

The density and quality of bone depends on the age of the patient, genetic factors, the location selected, and the functional load in that area. The density and thickness of the *Substantia corticalis* (*Substantia compacta*) and the *Substantia spongiosa* vary according to region. As previously described (see section 3.3.1.2), the thickness of the cortical bone is the most important factor for retention of mini-screws^{155,156}. If a mini-screw is to be inserted into the bone, a space for that mass must be created. For self-tapping screws, a pilot drill is used to remove osseous material. With self-drilling screws (i.e. no previous perforation of the corticalis with a pilot drill), space is created primarily by displacement of bone. This compression of bone contributes to the primary stability of the mini-screw. The thread and shank are designed to maximize primary stability and will be described below. The importance of shank length and diameter were previously described in section 3.3.1.2.

Ascent and Design of the Thread Shapes

If a screw is turned clockwise or counterclockwise by one full rotation (360°), then it will also move into or out of the medium into which it has been inserted. The amount of this movement per rotation, as related to its longitudinal axis, is referred to as its ascent and depends upon the distance from one thread shape to another. The degree of the ascent chosen greatly depends upon the nature of the material into which the screw is to be inserted. If the screw moves within a metal body, as for example, the spindle of palatal expansion screws, the ascent must be small. Relative to ti-

tanium or titanium alloy, bone is relatively soft; perhaps analogous to the situation of wood screws inserted into wood. From wood screw engineering, “softer” materials require a larger ascent for solid retention compared to metal screws in “harder” materials. A thread ascent of approximately 0.8 mm has been shown to be optimum for bone screws¹⁵⁷. It may seem reasonable that mini-screws should have the same thread ascent. Interestingly enough, some types of AbsoAnchor also have a very fine thread, with a smaller ascent, that may adversely affect retention.

The relationship between the shaft diameter (inside diameter) and the thread diameter (external diameter) is another determining factor for mini-screw stability. The quality and quantity of the different osseous layers also plays a very important role. In the relatively hard cortical plate (*Substantia corticalis*), the difference between the external and internal diameter should be 0.4 mm to 0.6 mm. In contrast, a larger difference is desirable in the softer *Substantia spongiosa*. The total dimension of the mini-screw, as well as the stability of the specific material it is inserted into, sets the limits. It is the portion of the screw within the cortical bone that is most responsible for retention, and therefore deserves the most attention.

The thread design – primarily, the form of the thread shape – has the most influence on the bone/implant contact¹⁵⁸, on the stress load of the bone^{159,160}, and on the insertion torque¹⁶¹. There are substantial differences between thread designs of popular mini-screws. It is possible that FEM analysis can be used to optimize thread designs for specific requirements.

Self-tapping or Self-drilling Thread – Which is Better?

The geometry of thread flanks and the screw tip determine whether a screw is self-tapping or self-drilling. The question of whether one is better than the other cannot be answered with a simple “yes” or “no” as there are many factors to consider. Using an analogy to wood screws may be useful to demonstrate this point. Imagine inserting a screw into a piece of hard wood. Without pre-drilling, substantial force, dependent upon the hardness of the wood and the diameter of the screw, is likely to be required.

Before the threads of the screw can bore into the wood, there may be difficulty in simply

stabilizing the direction of the screw in the hard surface. This is due to the fact that the resistance to boring is high, especially if the angle of insertion is not ideal for the threads to begin cutting. In these circumstances, the boring process may have to be started several times until threads finally grip into the surface. However, there is also the possibility that the insertion process starts and the tip of the screw is moving at different angles. The hole in the wood around the screw point will be widened. As a result, the screw may not be entering in the direction desired. Unfortunately, this may not be noted until after a few rotations of the screw. A re-correction of insertion angle, by unscrewing and re-screwing in the same hole, may not be possible. Depending on screw diameter and the thickness and flexibility of the wood, it may be almost impossible to turn the screw the last few thread flanks of the screw or the wood could fracture.

These problems could be easily avoided by pre-drilling a pilot hole in the wood before the insertion of the screw. The diameter and the depth of the pilot hole depend on the hardness of the wood and the diameter of the screw. The angulation of the pilot hole is a decisive factor, because the screw will inevitably follow. However, it is considerably easier to adjust the angle of the drill, as then it will quickly penetrate the wood while maintaining the original angle. In this scenario, the wood is not substantially compressed and the screw will not be subjected to strong torsional load. It appears, therefore, that in some circumstances, pre-drilling may be beneficial.

Self-tapping mini-screws require pre-drilling a pilot hole to a depth and diameter that correctly corresponds to the dimensions of the screw⁶⁸. Pre-drilling should be accomplished at a speed of no more than 800 rpm to avoid overheating the bone. In addition, adequate cooling of the drill is necessary. The drilling technique is also important (see section 3.5.2). A separate step of thread cutting or tapping, as is used in some implant systems, is not necessary for mini-screws. After the pilot hole is pre-drilled, the self-tapping screw is inserted. Typically, these screws have a blunt point and more rounded flanks. These flanks do not have to displace as much bone, and cut into the walls of the hole (Fig. 3-10). The blunted tip may prevent inadvertently drilling into a root⁷⁹. Since very little osseous substance has to be removed, compressed or displaced, there may be



Fig. 3-10 The self-tapping thread of Spider Screw (left) and tomas®-pins (right).

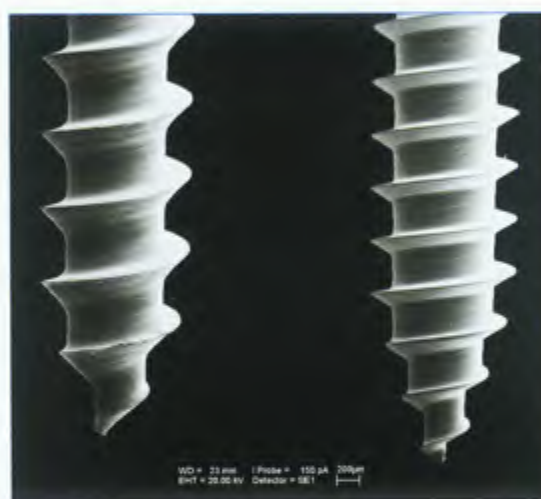


Fig. 3-11 The self-drilling thread of Dual-Top® Screw (left) and LOMAS screw (right).

less pressure necrosis. Most patients also feel minimal discomfort, a few hours later, due to this lack of pressure.

As the name suggests, a self-drilling screw (specifically a screw with a self-drilling thread) bores itself into the insertion medium. These mini-screws are promoted for insertion without pre-drilling. Although this appears to be an advantage, some factors must first be considered, such as the patient age, location selected for the screw, and the quality of bone. Bone is somewhat elastic so the sharp tip and thread flanks of a self-drilling screw can typically bore and cut into bone (Fig. 3-11) as the screw is advanced. Successful self-drilling depends on screw diameter and the degree of hardness and density of the cortical bone. The volume of bone that must be displaced by the screw is relatively high, so bone is strongly compressed.

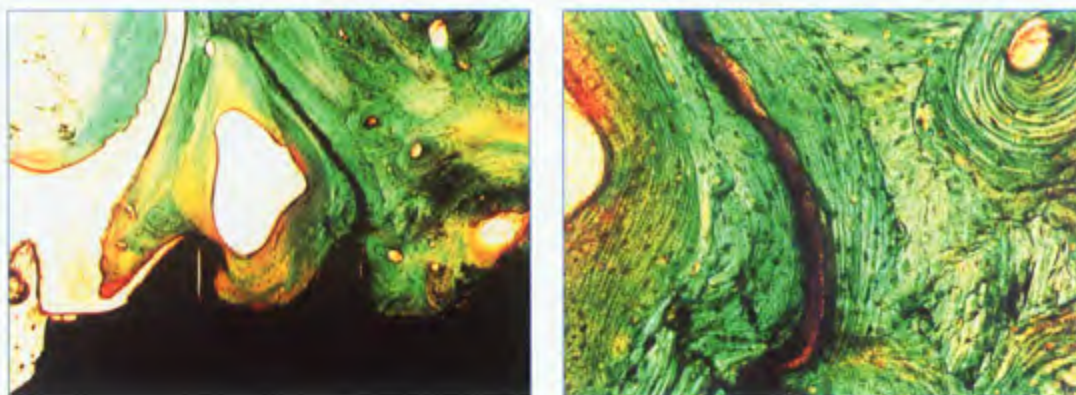


Fig. 3-12 After insertion of a self-drilling screw micro-ruptures were found inside the bone (photo: Dr. B. Böhm, Obertshausen).

The tension within the bone is also high. As a result, patients often feel some discomfort for several days after insertion of this type of screw. Böhm and Fuhrmann¹¹ discovered ruptures in the bone around self-drilling screws (Fig. 3-12). Pressure necrosis could also result. Significant resistance may have to be overcome when self-drilling screws are inserted into dense and/or thick cortical bone. During insertion, the screw may be exposed to substantial loads. If the cortical bone is thicker than 1 mm and/or the bone is very hard, the necessary torque required for insertion rises exponentially with the depth of penetration. Strong tensional forces develop within the screw that could prevent complete insertion or produce fracture^{162, 165}.

The basic concept for the development of the self-drilling mini-screw was to eliminate the need for pre-drilling. A more palatable compromise to avoid the previously described complications, especially patient discomfort, may be pre-drilling just through the cortical bone prior to inserting a self-drilling screw. Once through the cortex, a self-drilling screw can easily advance through the spongiosa. A common location where a pilot hole is probably not necessary is in the buccal alveolus, distal to the maxillary second molars.

The trend in the international market appears to be toward self-drilling screws^{12, 106, 174, 284}. Nearly all brands of mini-screws now offer products with self-drilling threads (Table 3-6; see also Table 3-10). The first generation of the Spider Screw¹⁰⁷ and tomas®-pin were self-tapping, but now both companies offer self-drilling versions.

Since it may be difficult to control the direction of insertion of a self-drilling screw, there is a greater risk for injuries to roots¹⁰⁶. The design of the thread influences the moment required to screw in the implant. For example, self-drilling screws produce a greater moment of force than self-tapping screws (with a previously prepared pilot hole in the pelvic bone of pigs)¹⁷⁵. The insertion torque or resistance to insertion influences the retention of the screw; however, this does not relate directly to the rate of loss¹¹⁶. Although a high degree of primary stability is certainly a goal to aspire to, the surrounding bone must also remain vital¹⁰⁶. Kim et al reported that self-drilling screws demonstrated less mobility and more osseous/implant contact^{67, 139, 140}. Currently, there is no evidence that self-drilling screws have a better clinical prognosis compared with self-tapping screws¹⁷¹. Kim and Choi¹⁰⁶ reported the rate of premature loss for self-tapping mini-screws was 34% and for self-drilling screws was 64%. In contrast, Woo et al¹¹⁶ did not find a difference between self-tapping (12%) and self-drilling (14%) mini-screws. It seems that both types of screws can be used successfully. So for areas that typically have cortical bone that is thinner and less dense, self-drilling screws are preferred. However, in areas where thick and dense cortical bone is anticipated, it may be more sensible to consider pre-drilling and placement of a self-tapping screw. If the status of the bone is questionable or the cortical bone is more than 1 mm, then first drilling a pilot hole through only the cortical bone can also be followed with a self-drilling screw¹⁷².

So, is the self-drilling or self-tapping screw most advantageous? As is often the case, the truth lies somewhere in between as both variations have been successful. The cautious practitioner might select self-drilling screws for maxillary applications and self-tapping ones for the mandible. We would like to reduce post-operative pain and also maintain an inventory of those screws that will cover most indications. As a result, the most important aspects of self-tapping and self-drilling (drill-free) mini-screws are summarized in Table 3-7.

Right-handed Thread and Left-handed Thread

Screws with a so-called right-handed thread are placed with a clockwise rotation and those with a left-handed thread are inserted with a counterclockwise rotation. All mini-screws are available with a right-handed thread. There is debate as to whether a screw with a left-handed thread would be an advantage. In a few clinical circumstances, forces may be applied to screws with a right-handed thread that may tend to unscrew them. This problem arises if square or rectangular wires are applied to a mini-screw with a single or cross-slot that may subject the screw to rotational forces that may be in an "unscrewing" direction. When using round wires, elastic chains or springs (direct anchorage), these rotational forces do not occur.

The AbsoAnchor, the Ancotek screw and CAplant are the only systems that offer screws with a left-handed thread (see Table 3-10), but is it absolutely necessary? To date, there have been no reports that a rotating load has led to loosening or premature loss of a mini-screw. A certain amount of torque is required to loosen a screw – the unscrewing torque. If one begins to unscrew a mini-screw, resistance must be overcome before the screw begins to move. The highest resistance to initiate counter rotational movement of the screw is in the first 5° of rotation movement. The degree of resistance depends on several factors, including the form of the threaded shank. Screws with cylindrical shanks are more difficult to move compared to those with a conical shape. A well-retained mini-screw (i.e. one with excellent primary and secondary stability) will require more torque to initiate the rotation to unscrew compared with the torque required for insertion²⁰. Chen et al²⁷ reported that greater than 8.9 Ncm of torque

Table 3-6 Design of thread and shank

Mini-screw name	Design of thread			
	Self-drilling	Self-tapping	Cylindrical	Conical
Aarhus-Mini-Implant	x		x	
AbsoAnchor	x		x	
Anchor Plus/NeoAnchor Plus	x			x
Ancotek	x		x	
Dual-Top Anchor Screw	x		x	
LOMAS	x		x	
MTAC	x			x
O.A.S.I.	x		x	
Orlus	x			x
Ortho Anchor Screw	x		x	
Ortho Easy®	x		x	
Ortho Implant		x		x
Orthoanchor		x	x	
Orthodontic Mini Implants	x		x	
Orthodontic Mini-Implant	x			x
Spider Screw	x	x	x	
tomas®-pin	x	x	x	

Table 3-7 Comparison of self-drilling and self-tapping thread

Characteristic	Mini-screw	
	Self-tapping	Self-drilling
Patient's comfort after insertion	• High • Post-operative pain disappears within hours	• Low • Post-operative pain for some days
Pilot drill	Necessary	• Primarily not necessary • Recommended for corticalis bone with a thickness of > 1mm
Observation of the direction of insertion	Easy, because ... screws follow the path created	Difficult, because ... screws create their own path
Widening of the bone entrance hole	Not possible	Possible
Insertion torque	Acceptable to moderate	Moderate to high
Warming of the bone during screwing	Low	High
Primary stability	Present, but depends on the pilot hole	Present
Danger of fracture	Low	Present
Time for insertion	Low	Low

was required to initiate mini-screw removal. Torque is the product of force (N) and length of the lever arm (centimeters). With the help of a small arithmetic example, perhaps it will become clear that screws with a left-handed thread are redundant. If one had a screw with a 2 cm lever arm and 8 Ncm was required to unscrew it, then a force of 4 N would be required; an amount that is well beyond that typically used to move teeth in orthodontics. The screw is the pivot point for the rotation and if a lever arm of 2 cm is rotated by 5° around the axis of the screw, then the end of the lever arm would move 1.74 mm. With a lever arm shorter than 2 cm, more force would be required to produce the same rotation and, in contrast, a longer lever arm would require less force. We have not even considered the flexibility or resilience of the wire (lever arm) in these calculations.

It may sound plausible that sufficient torque could be produced in some orthodontic applications to loosen a mini-screw. However, when the actual dimensions are evaluated, it becomes clear that it is unlikely. So, the need for a screw with left-handed thread, indeed, seems to be theoretically necessary, but in reality is not.

Actually, it is preferable to design orthodontic mechanics that avoid the production of a rotational load on any mini-screw (either clockwise or counter-clockwise). This is independent of whether the mini-screw has a right-handed or left-handed thread.

Cylindrical or Conical Shank – Which is Better?

The shank is the basic body of a screw from which the threads will be cut. Mini-screws typically either have a cylindrical or a conical shape. So, which shape is better for a skeletal anchorage with mini-screws? When all aspects are considered, the cylindrical shaft offers more advantages⁹¹.

Poggio et al⁹² concluded that mini-screws should have a length from 6–8 mm and a conical shaft. Cylindrical shanks require less torque to insert than conical ones^{93,94}. This depends on the angle of insertion and the thickness of cortical bone. Shortly before the mini-screw is completely inserted, it must significantly displace or compress the bone. In addition, corresponding resistance must be overcome, resulting in higher insertion torque. The screw gets

“stuck” in the area close to the head with very few threads or length of shank remaining to be inserted. Stronger compression would be desirable in the area of the screw tip in the softer, spongy bone. Nearer to the head, the screw’s diameter would have to be thinner to reduce compression. Such a “reverse cone” would complicate or prevent screw insertion. Moreover, the smaller diameter of the screw in the cortical bone would provide minimal anchorage and could be a site of screw fracture.

A cylindrical screw produces consistent compression of the bone over the total length of the shank, thereby exposing the bone to less stress. In contrast, screws with conical shanks quickly lose their hold within bone when unscrewed⁹⁵. Therefore, there is less danger of fracture during the removal procedure⁹⁶. With a rotational load in the unscrewing direction, a cylindrical shaft produces more resistance than a conical one. As a final consideration, Jang reported that cylindrical screws had an 88% success rate while conical ones exhibited a 95% success^{97,98}. The important factors to consider when selecting either thread shank are summarized in Table 3-8.

Ratio of Shank to Transgingival Collar, Depth Stop

The transgingival collar of all mini-screws has a larger diameter than the shank. There is a transition from the shank portion to this collar that may occur smoothly or in the form of a step or depth stop. During insertion, when the transgingival collar hits the osseous surface, there should be a perceptible stop to indicate that no further rotation should be attempted. Depending on the clinical circumstances (i.e. osseous quality, angle of insertion and the technique), this stop may or may not be felt by the operator. If the mini-screw features a smooth, continuous transition between the shaft and the collar, the diameter of the shaft dramatically increases, thereby preventing deeper penetration of the screw. If, at this point, the screw has been inserted to its full length, there are two possibilities if additional rotational force is delivered. Depending on the screw design and the flexibility of the bone, additional torque application will either cause fracture of the screw or the screw will simply spin within the bone. In the latter situation, the torque declines rapidly and diminishes the primary stability. The end result will likely be loss of the screw during the functional period.

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A cylindrical screw produces consistent compression of the bone over the total length of the shank, thereby exposing the bone to less stress. In contrast, screws with conical shanks quickly lose their hold within bone when unscrewed³. Therefore, there is less danger of fracture during the removal procedure³³. With a rotational load in the unscrewing direction, a cylindrical shaft produces more resistance than a conical one. As a final consideration, Jang reported that cylindrical screws had an 88% success rate while conical ones exhibited a 95% success^{34,35}. The important factors to consider when selecting either thread shank are summarized in Table 3-8.

Ratio of Shank to Transgingival Collar, Depth Stop

The transgingival collar of all mini-screws has a larger diameter than the shank. There is a transition from the shank portion to this collar that may occur smoothly or in the form of a step or depth stop. During insertion, when the transgingival collar hits the osseous surface, there should be a perceptible stop to indicate that no further rotation should be attempted. Depending on the clinical circumstances (i.e. osseous quality, angle of insertion and the technique), this stop may or may not be felt by the operator. If the mini-screw features a smooth, continuous transition between the shaft and the collar, the diameter of the shaft dramatically increases, thereby preventing deeper penetration of the screw. If, at this point, the screw has been inserted to its full length, there are two possibilities if additional rotational force is delivered. Depending on the screw design and the flexibility of the bone, additional torque application will either cause fracture of the screw or the screw will simply spin within the bone. In the latter situation, the torque declines rapidly and diminishes the primary stability. The end result will likely be loss of the screw during the functional period.

Characteristic	Shank	
	Conical	Cylindrical
Compression of bone	Mainly with the shank and the thread in the upper part	Mainly with the thread, but over the whole length
Risk of breakage between collar and head	Low	Present
Ease with load in unscrewing direction	< 180°	> 180°
Resistance during removal	Low to moderate	Moderate to high

Table 3-8 Comparison of cylindrical and conical shanks

3.4 Accessories in the Delivery Program

When evaluating mini-screws, one should not only concentrate on the screw design, but also on the associated accessories (e.g. drill, insertion tools). The functional design of the individual instruments, as well as their congruence and fit, are important factors for successful insertion. The number of accessories is to be observed: as few as possible, but as many as is necessary. Accessories are needed for perforation of the gingiva, pilot drilling and insertion (manual and mechanical). Too many parts confuse and can lead to mistakes. For mini-screw systems that feature multiple head designs, it would be preferable that only one type of insertion instrument would serve for each one. With Dual-Top® (Fig. 3-13), AbsoAnchor and Spider Screw® this is not the case; different drivers are needed for the different screws.

In an instrument tray, these devices should be clearly arranged in the sequence of working steps. During insertion, the instruments must be easily taken from the tray when using sterile gloves. A vertical arrangement of the instruments may facilitate these clinical procedures (Fig. 3-14).

3.4.1 Aids to Find and Mark the Insertion Position

The insertion location of a mini-screw is determined on the basis of radiographs, models, and clinical examination. The intent is to place the screw for best mechanical advantage, with the best hopes of survival, and without injury to vital structures, especially the roots. Wire elements are recommended as guides to find and mark the insertion position^{79,107,115}. As examples,

Clinical Procedure for Positioning

► Instruments

Item	Image	Code	Applicable Screw				
			JA	JB	JD	DI	DI2
Driver Shaft	for Screwdriver Body	 113-MD-103	●				●
		 113-MJ-103	●		●		●
		 113-JB-101		●			
		 113-MD-101	●				
		 113-GD-101				●	●
	for Contra Angle	 113-MD-203	●				●
		 113-MJ-203	●		●		●
		 113-MD-202	●				●
		 113-JB-201		●			
		 113-MD-201	●				
Drill	 113-GD-201	113-GD-201				●	●
	 112-MC-201	112-MC-201	●	●	●	●	●
Screwdriver Body	 111-092	111-092	●	●	●	●	●
	 111-112	111-112	●	●	●	●	●

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Fig. 3-13 In some systems the number of insertion instruments is high, because the different screw heads of the system cannot be inserted using the same instrument (picture: Dual Top, Jeil Medical Corp.).



Fig 3-14 The vertical position of the instruments inside the tomas®-tray make their removal very easy during insertion (picture: Dentaurum).



Fig. 3-15a Locator (prefabricated wire element) to mark the insertion point (photo: Prof. C. Morea, University of Sao Paulo).



Fig. 3-15b The insertion point is marked using an explorer (photo: Prof. C. Morea, University of Sao Paulo).



Fig. 3-16 The use of a spicular locator.

Fig. 3-16a The X-ray pin (Forestadent) on the left and the tomas®-X marker with pre-fabricated safety cord (Dentaurum) on the right.

Fig. 3-16b The X-ray pin (Forestadent) in position (photo: Dr. B. Ludwig, Traben-Trarbach).

Fig. 3-16c The X-ray pin (Forestadent) in the radiograph (photo: Dr. B. Ludwig, Traben-Trarbach).

Fig. 3-16d The Ortho Easy® mini-screw is placed at the desired position (photo: Dr. B. Ludwig, Traben-Trarbach).

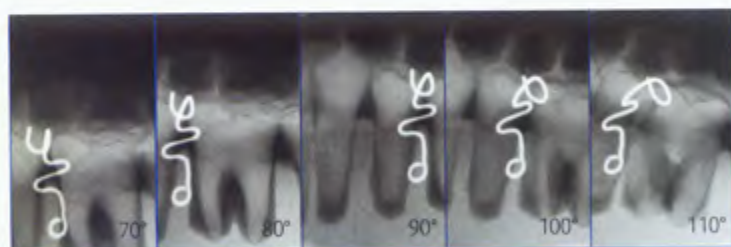


Fig. 3-17 The position of the eyelet was not changed for all radiographs. The angle between the X-ray tube and X-ray film was changed. Plus or minus 10 degrees from square or right angle (perpendicular) leads to false positive results. An artificial skull was used for the pictures.

wire segments (e.g. guide bar, locator), with or without an eyelet, can be used as a reproducible landmark. Using silicone or acrylic material, the guide can be "keyed" onto the occlusal surfaces of the teeth with the wire pointer or eyelet adjusted to the site selected for mini-screw insertion (Fig. 3-15a). After appropriately coordinating the wire segment to an appropriately paralleled radiograph, the insertion point can be marked (Fig. 3-15b).

Some mini-screw systems include pre-fabricated wire segments (Table 3-10). The use of these elements is relatively time-consuming. Ludwig et al¹⁰¹ introduced a small analog called an X-ray pin (Fig. 3-16a) to help accurately locate the site for a mini-screw. After topical or local anesthetic is introduced at the planned insertion site, a sterile X-ray pin is simply pressed through the soft tissue to the bone (Fig. 3-16b). After taking a radiograph (Fig. 3-16c),

the location of the X-ray pin can be compared relative to the adjacent roots. If the location must be adjusted, the pin is moved and another radiograph is taken for comparison. The pin is subsequently removed, providing a small "bleeding point" to mark the location for screw insertion (see section 4.1.3).

The accuracy of any of these X-ray aids is dependent upon the accuracy of the cone-parallel technique. In other words, the interpretation of optical distortion on a radiograph may lead to false positive or negative results (Fig. 3-17), so that a mini-screw may still be driven into an inappropriate position (i.e. near or against a root). Therefore, clinical observation should still be the decisive factor in mini-screw site selection.

Beginners might find X-ray aids extremely useful, but with increased experience these locators may not be required. It is important to note that although these location devices may be helpful in site location, they are not absolutely reliable. For example, an eyelet may indicate the insertion point but wide variations in the insertion angle of the mini-screw, in any direction, are also still possible.



Fig. 3-18 Pre-sterilized gingiva punch for single use only (picture: Dentaaurum).

punches (Fig. 3-18), especially since a fresh, new punch will be sharper and more reliable than one that has been subjected to repeated use.

3.4.2 Instruments for Soft Tissue Perforation

When mini-screws are inserted, perforation of the gingiva is required. There are three possibilities for perforation whose advantages and disadvantages are explained in section 3.5.2. The first option is the incision of the gingiva (i.e. stab incision), but this procedure is rarely done with mini-screws. The second option involves inserting the mini-screw directly through the soft tissue without any prior perforation. In this scenario, the mini-screw is the perforating device. The third variation is to use a mucosal or biopsy soft tissue punch to remove the gingiva that overlies the site where the mini-screw will be inserted into the bone.

A scalpel is required to make an incisional access but no mini-screw systems include a scalpel. In contrast some manufacturers recommend and include gingival punches. There are two variations available: disposable or sterilizable punches. Considering the small dimensions involved, cleaning and sterilization of the punch may be time-consuming or expensive. It may make more sense to use disposable

3.4.3 Pilot Drill

The most popular mini-screws are self-drilling and require no "pre-drilling". Nevertheless, most manufacturers still include a pilot drill in their system (see Table 3-10). As previously explained (see section 3.3.4), it may be preferable to at least perforate the cortical plate with a pilot drill, even when using self-drilling screws. Pilot drills of different diameter should be specific to the diameter of the screw, but also must take into account different osseous qualities.

Design of Pilot Drills

The most important parameters of a pilot drill are its length and diameter. Of course, the diameter of the pilot drill has to be smaller than the external diameter of the screw. If a drill had the same or a larger external diameter than the mini-screw to be used, there would be no primary stability as the threads would not be anchored in bone, resulting in premature loss of the screw³⁸. *Gantous* and *Phillips* recommend that the diameter of the drill should be 70–85% of the external diameter of the screw³⁸.

Fig. 3-19 Pilot drill with depth marker, depth stop and color code for easy identification, e.g. tomas®-drill 1.1 (picture: Dentaurum).



This means that for a mini-screw with a diameter of 1.6 mm, a drill with a diameter of 1.2 mm should be used. It is also important that the drill diameter is not greater than the inner diameter of the screw's shank.

The size of the pilot hole depends on not only the drill's diameter but also the osseous quality, the precision of the drill, and the user's ability. For a mini-screw with a diameter of 1.6 mm, the drill should have a diameter of 1.0, 1.1 or 1.2 mm, depending on osseous quality and insertion area. The difference of the diameters of screws and drills vary from 0.3–0.7 mm within single systems as well as the among the different screw types^[14,103,115]. The necessary length of the drill is determined by the length of the screw selected. Not every length of screw needs its own corresponding drill. Drills that have a depth marking are preferred. The depth stop prevents unintentional over-penetration of the bone. Conical or cylindrical reinforcement of the drill body is available for pilot drills of AbsoAnchor, Spider Screw®^[107] and tomas®-pin (Fig. 3-19).

Application

Many mini-screw systems contain different pilot drills. Each should be clearly marked for easy identification for ease of use and maintenance (see Fig. 3-19). Pilot drills must be disinfected, cleaned thoroughly and sterilized before and after every use.

The adjustment of the pilot drill position and angulation will determine the position of the mini-screw^[116]. As already shown (in section 3.3.4), the direction of implant insertion can be determined much more exactly with the pilot drill than is possible with a self-drilling screw (in-

serted without pre-drilling). The actual drilling procedure must be a balance of effective drilling and also careful observation of the quality of bone. Indeed, slow drilling speed, combined with light pressure on the drill, saves the bone but requires more time. Faster drilling with a heavy hand will shorten time but will produce a damaging increase in bone temperature^[75,109]. A sharp drill, used at slow speed with copious cooling, will reduce the potential for overheating the bone and prevent necrosis. The literature describes a wide range of recommended drill speeds: 60–100 rpm^[107] and 500^[12] up to 1500 rpm. *Bumann et al*^[11] recommend 800 rpm if accompanied by sufficient cooling with sterile saline. With the small diameter of the mini-screw, internal cooling is probably implausible and also not necessary^[6]; however, external cooling (irrigation) with water from the typical dental unit is problematic. Continuous disinfection of water, to reduce the possibility of endotoxins^[107], would be required. Sterile, cooled (at 5°C), physiological saline solution, applied with a syringe during the drilling process is a simple alternative.

Melsen^[113] recommends that the pilot drill be inserted only once into the pilot hole to reduce the potential for carrying intra-oral organisms into the hole. The tool life of the drills is another consideration. Their frequent replacement is recommended, as the drills will become "dull" after several cycles of use and sterilization.

Center-drilling/Center Punch

In some circumstances (e.g. dense bone, difficult posterior access sites), pre-drilling can be quite difficult. The drill point may "slip" on the dense cortical surface before actually penetrating the bone. When the drill tip slips off the bone, the adjacent soft tissue can be torn or damaged. This problem occurs most often when attempting to drill at an angle and could result in the pilot hole being started in an unintended direction. Producing a "dimple" or marking the site with a "center-drill" can help to reduce these risks.

Center-drilling means to produce a small crypt, depression, or "dimple" in the surface of the bone at the intended mini-screw penetration point. After a dimple is created, then the pilot drill will be less likely to slip off as drilling is started^[9]. When drilling into metal surfaces, this type of center-mark is made by pounding

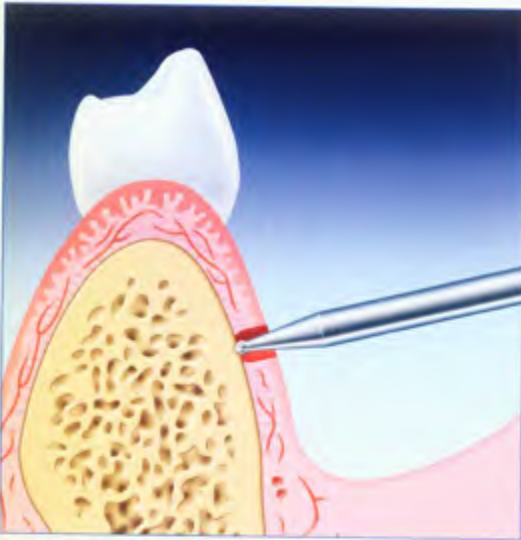


Fig. 3-20 For center-drilling of the bone, a round drill is used, e.g. tomas®-round (picture: Dentaureum).



Fig. 3-21 The fixation of the screw inside the insertion instrument is realized with internal coupling (see first and third from above) or external coupling (see second or fourth from above) (photo: Jeil Medical Corp./Promedia).

an indentation mark into the material. Obviously, this is impossible when working with patients. A 1 mm spherical drill (rose drill) (Fig. 3-20) or a small round bur can be used to "dimple" the bone. This center mark is most critical for patients with dense bone, especially the greater the angle of implant insertion. Another advantage to center-marking is to evaluate osseous hardness before pilot drilling is initiated. A differentiation between D1 and D4 bone density may be possible, but is unlikely between D2 and D3¹⁶⁹.

3.4.4 Instruments for Insertion

The method of insertion for a mini-screw, along with the previously mentioned factors, can dramatically influence the final result. Consequently, the instruments used to insert and remove mini-screws are critical. Most important is the coupling between the driver and screw to enable the application of controlled and correct amounts of torque. There are two variations for this driver/screw connection: the instrument couples either internally or externally to the mini-screw (Fig. 3-21). External coupling is often achieved using some type of square, hexagon, or octagon socket. Since mini-screws are quite small, external connection provides a safe, stable, and effective method as the torque is dis-

tributed over a relatively large surface. The matching hexagonal or octagonal shape is often incorporated into the shape of the screw head, as for example, with the Aarhus-Mini-Implant, Spider screw® and tomas®-pin. As an alternative, the shape may be incorporated into the transgingival collar such as with some types of AbsoAnchor and LOMAS screw. If the driver's action is located on the transgingival collar, there is the possibility that the gingival tissues may be impinged during insertion (section 3.3.3).

If the driver couples internally with the mini-screw, then the driver is often a modified "Phillips" screwdriver or spline driver that couples with a slit or cross-slot in the head of the screw. Examples of internal coupling instruments include the Dual-Top JA, Ortho Anchor Screw (KLS Martin) and MTAC Screw (American Orthodontics). In these scenarios, the contact area between the driver and screw is smaller. As a result, greater force must be transferred from the insertion instrument on the screw per surface unit than with external coupling. Depending on the force required to overcome the resistance for driving the screw, the connection between instrument and screw may "slip". This slippage or loss of connection could result in mechanical distortion (e.g. "stripping" the walls of the cross-slots) or breakage in the projection area¹⁷⁵. This phenomenon is



Fig. 3-22 Manual insertion instrument with spring element to hold the screw (picture: Dentaaurum).



Fig. 3-23 With the help of the rubber ring the ball works like a spring and fixes the mini-screw inside the insertion instrument.

like that seen when a wood screw is placed, without pre-drilling, into a hard wood. As additional torque is applied to overcome the resistance of the wood, the screwdriver may slip out of the head of the screw. In doing so, the walls of the slots may be damaged or distorted, thereby rendering the screw useless.

The mini-screw must also be firmly and safely fixed in the insertion instrument to carry it to the insertion site (see also section 3.3.2). After insertion, however, the instrument should also be easily drawn away from the screw. This connection between the driver and the screw is often derived by friction. This requires an ideal fit between both parts and relatively long, vertical, holding surfaces. Due to the small dimensions of mini-screws and the manufacturing tolerances involved, this type of friction-based connection is not easy to achieve. Manufacturers offer different solutions to increase the frictional connection for a "safe hold" of the screw. One variation is to slit the projection area (Fig. 3-22) of an externally connected driver. A "tongue" (tine or tiny spring) is included in the head of the driver to fix the screw in position. Unfortunately, the flexibility of this tongue may diminish over time and necessitate frequent replacement of the driver. Another possibility is the integration of small metal balls into the construction of the driver's projection. Two small metal balls lie in a ridge at the end of the projection and are designed to retain the mini-screw in the driver. These are held in place with an elastic ring (Fig. 3-23). Fissures can de-

velop between the driver's flange and the elastic ring, and the metal balls are difficult to keep clean or free from corrosion without disassembly. This kind of external driver fixation is used with the Abso-Anchor and Dual-Top® Anchor-Screw.

Removal of the driver from the inserted screw, whether it was inserted manually or with a handpiece, should occur with force applied strictly parallel to the long axis of the screw¹¹. Unfavorable mechanical loads on the screw head can, thereby, be avoided after insertion. There are two types of drivers: those for manual insertion and those for use with a handpiece. All mini-screw systems feature at least one instrument for manual insertion, but not all have one for use with a handpiece. There is only one study that compares both insertion procedures¹⁶. Mini-screws that were manually inserted exhibited a 11% failure rate, whereas those placed with a handpiece had a 28% failure rate. Whatever the method used for insertion or removal, it is during these procedures that screws are exposed to the highest loads.

Torque and Load of the Screw during Insertion

The torque required to insert and to remove a mini-screw is the vector product of the force necessary for rotation of the screw and its distance (distance vector to the axis of rotation (lever arm)). For example, a wood screw is eas-

ily driven with a long screwdriver with a large diameter handle (large distance = long lever arm). If a short screwdriver with small diameter handle is used (short distance = short lever arm), more strength has to be used to reach the same torque. If the same force is applied in both cases, the larger screwdriver produces more torque. This may result in more rapid insertion of the screw, but at the same time the resistance to insertion in the bone increases. Friction generates more heat and the torsional load in the screw increases and could increase the risk of fracture. As a consequence, caution should be exercised when using long drivers with large handles. The necessary torque to insert a mini-screw also depends on other factors. As was shown in section 3.3.4, the thickness of the cortical bone¹⁵, the diameter and the shaft design of the screw, the diameter and the depth of pre-drilling¹⁵ as well as the insertion technique¹⁶ all play a role. Insertion and removal should occur at a slow and steady rate with a low and continuous force so that the load on both the bone and the screw will be kept low.

All mini-screws are subject to breakage upon reaching a certain torque level. This maximum torque can be calculated and can be confirmed by experiments. Some manufacturers (see Table 3-10) report the maximum torque of their products, although this information seems somewhat questionable. There must be a distinction made between the recommended torque limit for screw insertion (highest admissible torque) and the maximum torque. There is a range between these two values where sufficient safety should occur. For the clinician, this recommended limit is very important to help prevent screw breakage¹⁷. Depending on all the factors mentioned previously, the recommendations for the highest admissible torque vary between 20 Ncm (e.g. tomas®-pin, Spider Screw®) and 40 Ncm for Ortho Implants (IMTEC)®. It also may not be ideal to achieve higher torque levels during implant insertion, as this does not guarantee a high survival rate. On the contrary, Motoyoshi et al¹⁸ reported that torque levels of between 5 and 10 Ncm have the best rate of success for a mini-screw with a diameter of 1.6 mm and a length of 8 mm. Higher or lower torques showed significantly lower survival rates. As described in the next section, there are only three screw systems for which the torque can be adjusted and controlled during insertion.

When self-drilling mini-screws are exposed to larger torque values (as may occur especially when no pre-drilling is performed), the bone will be significantly compressed, hotter, and presumably subject to more local necrosis. The overheated bone in that site may necrose and may not completely regenerate. This can result in delayed healing and reduced primary stability of a mini-screw¹⁹ and possible premature loss. When low levels of force are required for insertion, the mini-screw meets with little resistance. This may result with bone of low density or from unfavorable insertion methods. In these circumstances, the mini-screw may also fail.

The user's technique also plays a significant role in success. A steady hand is required to reduce adverse lateral torque on the screw. When inserting most screws (e.g. wood and metal screws), the fingers are fixed in position and the wrist is used to twist the screw. Due to the longer lever arm in this scenario, large torque values are produced. This is a concern for long drivers with large handles as the forces produced can be exceptional. Most manual drivers for mini-screws are designed to apply forces only using the thumb and index finger, not the wrist, thereby reducing the amount of torque applied.

Manual Insertion

Manual insertion of a mini-screw permits the user to get a feeling for the osseous quality at the insertion point and, in turn, the necessary torque. Depending on resistance of the bone, the torque applied to the mini-screw can be varied or controlled by the user.

For all mini-screw systems, drivers are available in different diameters and lengths. Shorter instruments have the advantage that they can be used in more locations and permit better control of torque. Unfortunately, these types of drivers, because of their smaller diameter and reduced length, require a greater degree of effort compared with the larger screwdrivers. In some systems, the short screwdriver can be linked with a wheel (Fig. 3-24). This attachment increases the effective lever arm of the insertion instrument, reducing the effort for insertion.

All manufacturers offer long screwdrivers for their mini-screws. With these longer instruments, the insertion of screws can be made with



Fig. 3-24 Small screwdriver – tomas®-applicator – with a knurl on top – tomas®-wheel – makes the manual insertion easier (picture: Dentaureum).



Fig. 3-25 The control of insertion torque during insertion is possible with a torque ratchet (picture: Dentaureum).



Fig. 3-26 When the desired torque is reached (a) the head of ratchet bends, preventing the application of adverse force levels (b) (picture: Dentaureum).

minimal effort but increased risk. Depending on the technique and the force required, high torque can develop. There is more risk of damage to the bone or breakage of the screw. Furthermore, the operator does not have the same "feel" for the bone as with the shorter driver.

Some screw systems offer ratchets, which are used in combination with short screwdrivers. Primarily, the ratchet is an auxiliary instrument to reduce the need to change hand position during insertion, a definite advantage for some insertion locations. Again, the effort required by

the user decreases when using the longer lever arm. On the other hand, the longer lever arm could result in forces over the maximum admissible torque unless the torque is adjustable at the ratchet. Ratchets without torque control are included with the Ortho Implant (Imtec) and Orthodontic Mini Implants (Leone). Torque control during insertion is preferable. Only the AbsoAnchor, LOMAS and tomas® systems offer a ratchet with variable torque control (adjustable between 5 and 30 Ncm) (Fig. 3-25). Once the adjusted torque level is reached when



Fig. 3-27 Tools for mechanical insertion of mini-screws.

Fig. 3-27a Surgical unit with preselection and control of speed and torque, e.g. INTRAsurg® 300 (picture: KaVo).

Fig. 3-27b Angled handpiece with reduction of speed (10:1 and max. 39 rpm) without control of torque (picture: NSK).

using the driver, the head of the ratchet “bends” and no further force is applied to the screw (Fig. 3-26). The driver can be turned even further, but with a higher torque than the previous limit.

How is the torque controlled during insertion? This was a question submitted to manufacturers in the questionnaire (see section 3.6). Three manufacturers (see Table 3-10, D-04: Anchor Plus screw, Dual-Top® Anchor Screw, Orlus) recommended tactile evaluation (by hand), which is probably not the best source of determining safe torque levels.

Mechanical Insertion

For mechanical insertion of mini-screws, special angled handpieces that can be adjusted to 25 rpm and limited torque are required. Suitable surgical units with these properties are common in prosthetic implantology (Fig. 3-27a) as they allow exact setting and control of RPM and torque, but they are very expensive. There are other special angled handpieces that feature the necessary gear reduction (Fig. 3-27b); however, they do not permit torque control. Mini-screws inserted using angled handpieces that permit setting constant torque, experience more consistent force application. This avoids the untoward peaks in torque levels that invariably occur with manual insertion methods¹⁰⁰.

Handpieces that do not permit adjustment of torque and rotational speed should not be used with mini-screws. The maximum torque



Fig. 3-28 An incorrectly angled handpiece was used to insert the screw, with high speed and no torque control, with the consequence of screw fracture (trial on a pig jaw).

can be very quickly exceeded and a fracture of the mini-screw (Fig. 3-28) can occur. Another disadvantage of handpiece insertion is that there is no tactile feeling of resistance of the bone or load application to the screw. There is also no time saving when using the handpiece compared to manual insertion. These special devices are relatively expensive at this time and are perhaps worthwhile only if a large volume of mini-screws is used.

3.5 Aspects Dependent on the System of Application of Mini-screws

The general insertion procedure for mini-screws is basically similar for all of the different systems (shown in Chapter 4). Depending on the philosophy of the system there are, however, differences in some details (Fig. 3-29) that may influence their effectiveness, burden for the patient and success of therapy. In addition to the preceding remarks, some further aspects are discussed below.

3.5.1 Delivery of the Screw

All mini-screws are medical products that are implanted into the body (if only temporarily) and, as such, in the European Union they are categor-

ized as class IIb medical products. The necessity of sterility for a mini-screw before insertion is beyond question. For instance, prosthetic implants are expected to be cleaned and sterilized after fabrication and then delivered in sterile packaging from the manufacturer. It is doubtful that clinicians would accept sterilizing them in their dental offices. It is surprising that this high level of industrial hygiene has not become the standard within the mini-screw industry. The first pre-sterilized mini-screws on the market were the Ortho Implant (IMTEC)¹⁴ and tomas-pin (Dentaurum)¹⁵. Subsequently, the LOMAS-Screws (Mondeal) and Spider Screw (HDC)^{16,17} are now also delivered in sterile packaging.

Sterilization is a routine process in medical facilities. There is more to the term "sterilization" than meets the eye as there are three separate steps in the process: disinfection, cleaning, and the actual sterilization itself. The whole process is carried out with the purpose of eliminating all forms of pathogenic and non-pathogenic microorganisms, including DNA/RNA viruses and prions but also particles and endotoxins/pyrogens. The result is a pure and sterile surface. The sterilized objects are free of microbic contamination by living cells, spores and other forms of microorganisms¹⁸. It is just as important, yet often underestimated, that the surface should also be free of any particulate matter and any endotoxins/pyrogens, since a sterile object is not automatically free of endotoxins. Even an object free of particulate matter may not be free of endotoxins¹⁹. Particles or residues left after manufacturing and/or endotoxins remaining on the surface of mini-screws may have a pathogenic effect after insertion. This undesired reaction can lead to premature loss. Of course, the effect of pathogenic substances is based on the dose, the site of introduction, and the susceptibility of the patient.

Despite the fact that a mini-screw is delivered in sterile packaging, it should not be subject to contamination from microorganisms, organic particles or other substances from the moment it leaves its packaging to the moment that it is inserted in the bone. Endotoxins are a special problem. They are released from dead microorganisms, especially gram-negative bacteria, and are a common cause of nosocomial infections in hospitals. A mini-screw contaminated with gram-negative bacteria could result in the release of endotoxins into the bloodstream, thereby creating a sys-

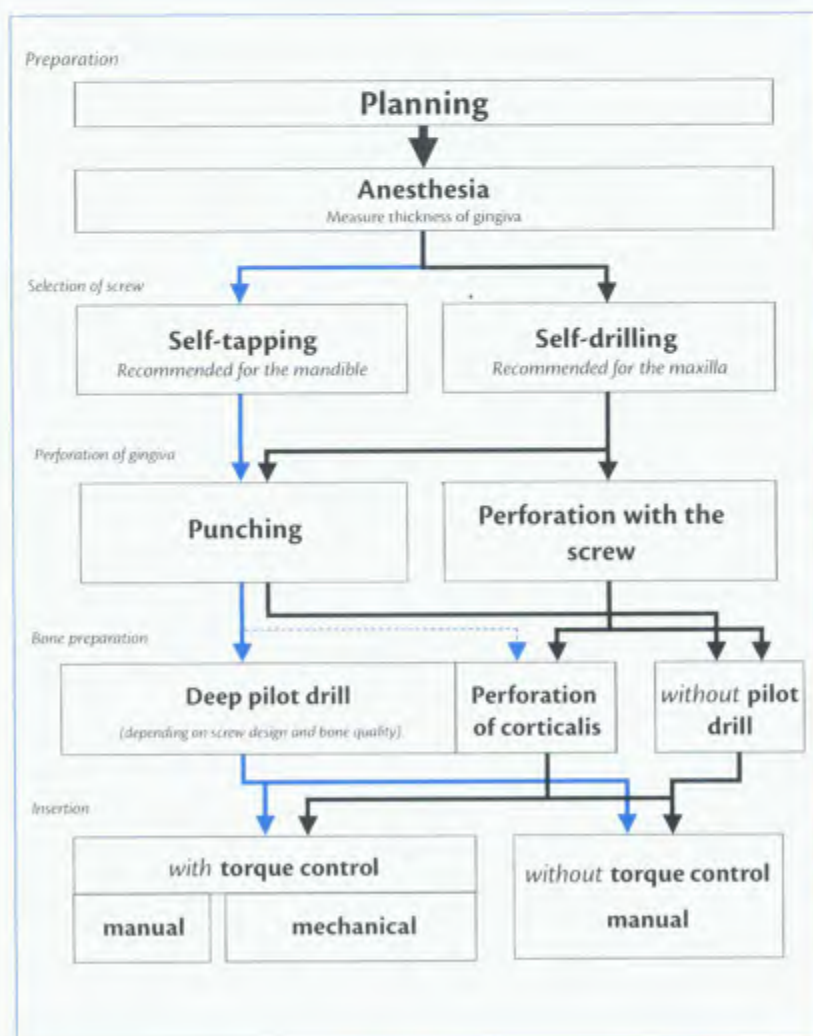


Fig. 3-29 The principles of inserting a mini-screw.

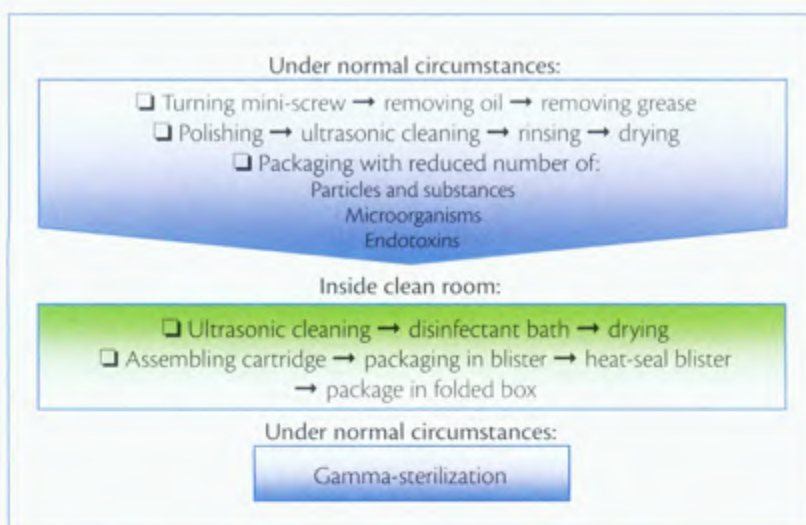


Fig. 3-30 Production process of a pre-sterilized mini-screw.

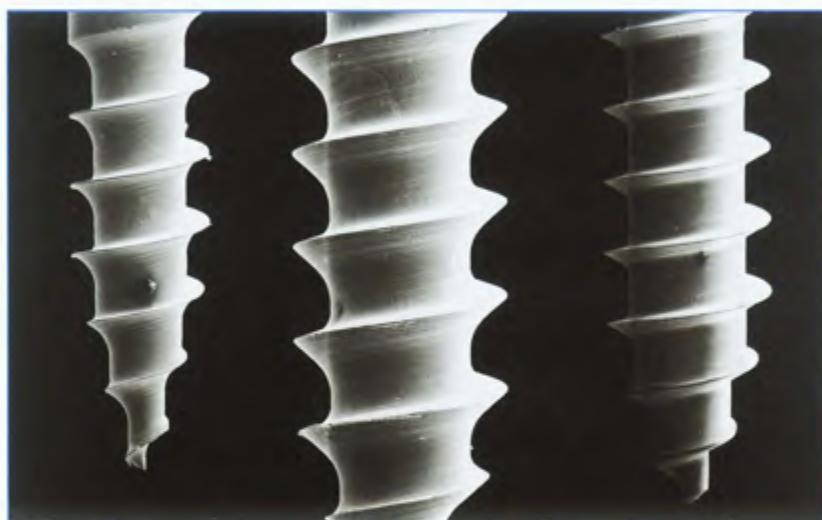


Fig. 3-31 Non-sterile screws after production have particles at the surface. This is inevitable for all mini-screws, e.g. Aarhus-Mini-Implant, Dual-Top® Anchor-Screw, LOMAS-Screw (from left to right).

temic problem⁷⁸. In addition, endotoxins on the surface of a mini-screw could cause adverse reactions in the bone adjacent to the screw^{14,30,129}, perhaps leading to osseous resorption¹⁵⁵. For example, the surface proteins of *Staphylococcus aureus* may cause bone resorption¹²⁵.

After fabrication of a mini-screw (Fig. 3-30), it is subject to thorough cleansing to remove the majority of inorganic or organic particles and substances, microorganisms, and endotoxins. Cleaning of the screws should be carried out according to a validated procedure. In a production process, this permits the best possible elimination of particles (Fig. 3-31), microorganisms and endotoxins. As a result, the screws must be cleaned, disinfected and sterilized before insertion³⁶². So should mini-screws be purchased pre-sterilized?

Pre-sterilized Mini-screws or Operator Sterilization?

The problem is not the process of sterilization itself. With sterilization processes used in a dental office, microorganisms can be eliminated as effectively as gamma-ray sterilization by a manufacturer. The problem is the disinfection and cleaning of the mini-screw before sterilization. Here is where the differences between a dental office environment and a specialized company are delineated. In the "clean" room (ISO class 7 and 8) of such companies, a repeated cleaning with pyrogenic-free water and disinfection in an extremely germ-reduced environment is carried out. Endotoxins can be removed by intensive mechanical cleansing of the mini-screw¹⁷⁸. This is facilitated by the smooth surface of a mini-screw compared to the rougher surface of a

prosthetic implant¹⁶⁷. The mini-screw is then inserted into a glass container with blister packaging before it is subjected to gamma-ray sterilization. These costly procedures result in a mini-screw that is free of inorganic and organic particles or substances, microorganisms and endotoxins at levels that are below acceptable or admissible values. Such results can be achieved only in a clean room where special equipment (hygiene locks, air pressure differences, etc.) and protective clothes for staff (protective bonnets, coats, gloves, etc.) reduce the amount of microorganisms within the manufacturing environment, an environment different from the typical dental office¹⁶⁸. The entire manufacturing process from cleaning to sterilization will be documented, validated and subjected to regular controls. Pre-sterilized mini-screws offer a higher security standard for both the patient and the operator, but, of course, have a price.

If non-sterile mini-screws are purchased, then the user is forced to provide the sterilization procedures. On the surface, this appears to be a routine daily procedure. However, this procedure can be affected by a series of procedural mistakes that could have adverse effects such as a higher rate of premature loss. For example, the mini-screw should only be touched using a sterile forceps and only at the head after it has been removed from its packaging and during the entire process from sterilization to insertion. If the threads of a mini-screw are touched, even with sterile gloves, this could still result in premature loss.

It is incorrect to simply sterilize a non-sterile mini-screw upon delivery as the surface may still be contaminated with particulate matter, endotoxins, microorganisms and cytotoxic materials (see Fig. 3-31). Any kind of contamination of the implant surface may compromise or inhibit favorable contact between screw and bone⁷⁹. Sterilization kills only microorganisms; the amount of particles and cytotoxins/endotoxins on the surface remains unchanged for the most part¹⁶⁹. The microorganisms have been killed, but what about the endotoxins? Sterilization may not necessarily render endotoxins ineffective because they are heat-stable up to approximately 180°C⁷⁸. Gram-negative bacteria are killed by sterilization, but then endotoxins may be released in the process. The bacterial cell walls of the dead gram-negative bacteria are destroyed and the endotoxins are set free. There-

fore, if mini-screws are simply sterilized in the dental office (without previous thorough disinfection and cleaning), the level of endotoxins may increase and could be another reason for premature loss of screws.

The correct procedure is as follows: the mini-screws should be removed from the manufacturer's packaging, cleaned thoroughly with pyrogenic-free water, disinfected, and packed again for sterilization. Even if the entire procedure described is carried out in the office, this is still no guarantee for a completely decontaminated screw. This is primarily due to the difference between performing these procedures in an industrial clean room with its germ and dust reduction as compared with the dental office environment.

The procedures for sterilization in the dental office must meet the regional hygiene regulations for the location of the practice. Even if those standards are met there are still some other considerations if non-sterile screws are selected¹⁶⁵:

- expenditure of time, energy and costs for manual cleaning, disinfection and sterilization, including necessary materials and instruments
- proof of the effectiveness of procedures for manual cleaning, disinfection and sterilization
- expenditure of time and costs for acquisition, supervision and disposal of the necessary chemicals
- production of detailed working instructions
- documentation of the entire process.

The complete responsibility and accountability for the application of non-sterile mini-screws lie with the user.

Calculations from hospitals for multi-use medical products have shown that the expenditure for these additional procedures is not cost-effective for products with a purchase price of less than \$65 or €40¹⁶⁵. The cost of disposable products makes more sense at that price. This is the typical cost of a mini-screw as well. Consequently, the decision between purchasing pre-sterilized or non-sterile mini-screws depends upon the costs (staff, material, energy) of cleaning and sterilization for the safety and security of the patient compared to the actual retail price of the mini-screw product. Considering all aspects it would seem that pre-sterilized mini-screws make more sense. Mini-screws that are supplied in a non-sterile form may affect the safety of the patient, but may appear to be less expensive. In actuality, they



Fig. 3-32 The label contains all the necessary information about the used mini-screw. The small labels should be used for the patient's file. With the REF and LOT number the doctor has all the important information in a compressed version (picture: Dentaurum).

may cost more. Pre-sterile mini-screws eliminate the entire process of preparation (cleaning, disinfection and sterilization), documentation and the requirements for local hygiene guidelines that should be fulfilled⁵⁰. Then it is acceptable to register the exclusive use of "disposable" products in the hygiene plan^{51,5}.

In addition, pre-sterilized mini-screws are ready for immediate use upon delivery, at any time. There are time constraints associated with preparing non-sterile mini-screws on an individual basis. Those mini-screws that must be sterilized in-office must undergo the previous steps prior to them being ready for clinical application.

Quality Management

Within the scope of quality control management, documentation is critical. It is important to be able to identify the source or lot-number for the mini-screws used for a particular patient, even several years after their insertion. In this manner, the mini-screw can be traced. The manufacturers maintain corresponding records and reserve samples from the same lot that are available for comparisons if needed.

Often attention to small details helps to make a particular mini-screw system easy to work with. For example, to simplify the record-keeping process, some mini-screws are supplied with a "peel-off" label or sticker. This label is printed with all of the appropriate identifying information for that particular mini-screw (Fig. 3-32). This information should be transferred to the patient's chart. For example, the tomas®-pin was the first to supply adhesive labels, printed with the mini-screw brand, type, size, order number and lot number. Subsequently, many other companies have followed suit.

3.5.2 Insertion of the Screw

The rate of success with mini-screws is dependent upon the insertion procedure, the skills of the operator, and his or her experience level on the learning curve with this technology. The precise influence of each of these parameters cannot be easily differentiated and should be subject to further clinical research. At this point, it might be useful to analyze each step in the process of mini-screw insertion, in view of both positive and negative experiences, to develop some suitable clinical recommendations.

Perforation of the Gingiva

In order to insert a mini-screw, it must, in some manner, perforate the soft tissue. Each mini-screw manufacturer recommends different methods for this procedure. This ranges from recommending an incision or "flap" exposure, a soft tissue or biopsy punch, to simply inserting the mini-screw directly through the soft tissue. At present, there is no definitive conclusion as to whether any of these methods directly affect the survival rate of a mini-screw.

Mini-screw pioneers followed the experiences of those involved with prosthetic implants. For instance, Kanomi (1997)⁵⁶ insisted upon a gingival flap incision of the mucosa to expose the underlying bone. The intent was to provide better visualization when drilling a pilot hole⁷⁴. The wound that was produced must then be approximated and sutured. This approximation may not provide an ideal seal of soft tissue to implant and could lead to further complications and greater post-operative discomfort. The gingival flap produces inflammation, pain and swelling for up to a week after

insertion^(111),116). There appears to be no advantage to flap surgery prior to screw insertion except in a few situations, as some manufacturers (e.g. Orthodontic Mini Implants and Leone) still point out. For example, developers of the Aarhus-Mini-Implant recommend that a 2–3 mm incision should be made prior to drilling a pilot hole when a mini-screw is to be placed in the mandibular symphysis⁽¹¹⁾.

It seems intuitive that if the insertion process is less invasive, then less post-operative discomfort will be experienced by the patient⁽¹⁷⁾. As the use of incisions has become less acceptable⁽¹⁾, the tissue punch or inserting screws directly through the soft tissue has become more prevalent (see Fig. 3-29). There is no publication that has described a definitive answer as to which is the better option in terms of post-operative problems, histological effects or the rate of loss. The effect of the chosen method of perforation is presumably linked with the design of the transgingival part of the mini-screw.

When a mini-screw is inserted directly through the soft tissue, small tears, wound edges, and local bruising may result. As a consequence, gingival healing is complicated and perimucositis or peri-implantitis could occur, especially if the head of the mini-screw is significantly larger in diameter than the transgingival collar (see section 3.3.3). In addition, basal or epithelial cells may be carried with the screw threads into the bone. From implantology, the quick proliferation of these cells could adversely affect implant stability by interfering with bone-implant contact.

Herman found that the removal of the mucosa over the insertion site results in a lower rate of loss⁽¹⁾. A soft tissue punch produces less pain than a gingival flap procedure^(60,112). In addition, the sharp biopsy punch produces a smoother wound edge that permits rapid tissue regeneration during the first days and healing that is nearly free of inflammation. Then, the cylindrical part of the punch instrument must be carefully debrided with a dental explorer or surgical tweezers after the punch procedure.

Depending on the design of the transgingival collar of the mini-screw, the soft tissue surrounding the area of perforation may seal to the collar immediately⁽¹⁸⁾ (Fig. 3-34). As such, mini-screws with smooth neck or collar areas would seem to be less susceptible to perimucositis or peri-implantitis.

Pilot Hole Drilling

Most mini-screws are now available with a self-drilling thread (see Fig. 3-29). Sections 3.3.4 and 3.3.3 provided a description of pre-drilling a pilot hole and the associated advantages and disadvantages. An increase in tension within the bone and an associated post-operative discomfort are the main concerns with self-drilling screws. In particular, if the self-drilling mini-screw is inserted near the alveolar ridge, the osseous displacement can lead to a strong dilation of the periosteum. This may result in prolonged discomfort for the patient.

The thickness of the cortical bone, especially in the mandible, is a factor in determining the degree of torque required for screw insertion^(100,120,136,137). Independent of the mini-screw system or thread type selected, it can be argued that the mandibular cortical bone should be always pre-drilled⁽¹⁾. However, if pre-drilling the entire depth of the mini-screw is not desired, at least the cortical bone should be perforated.

Insertion (Manual/Mechanical)

All mini-screws can be inserted into the bone using a specific screwdriver, although torque control is an issue (see Fig. 3-29). Depending on the design of the screwdriver, excessive torque can be unintentionally generated. As *Motoyoshi et al*⁽¹¹⁸⁾ reported, there is a correlation between the insertion torque applied and the rate of success. The lowest rate of loss occurred with a torque level between 5 and 10 Ncm for an 8 mm mini-screw with a diameter of 1.6 mm. To actually use this information in practice, you would need to be able to measure torque during insertion. Only the LOMAS screw and tomas®-pin systems offer torque control ratchets. If the maximum torque is adjusted to 10 Ncm and that level is reached during screw insertion, then the ratchet head will bend or “release” (see Fig. 3-26). If the torque remains below the adjusted value, the head remains intact. It is important that regular calibration of the ratchet should be confirmed.

Ratchets are also available for the Ortho Implant (IMTEC), Orthoanchor K1 (Dentsply Sankin) and Orthodontic Mini Implants (Leone), but they do not feature torque control. As such, their use could be problematic. The long lever arm of the ratchet reduces the effort by the user to achieve additional torque.

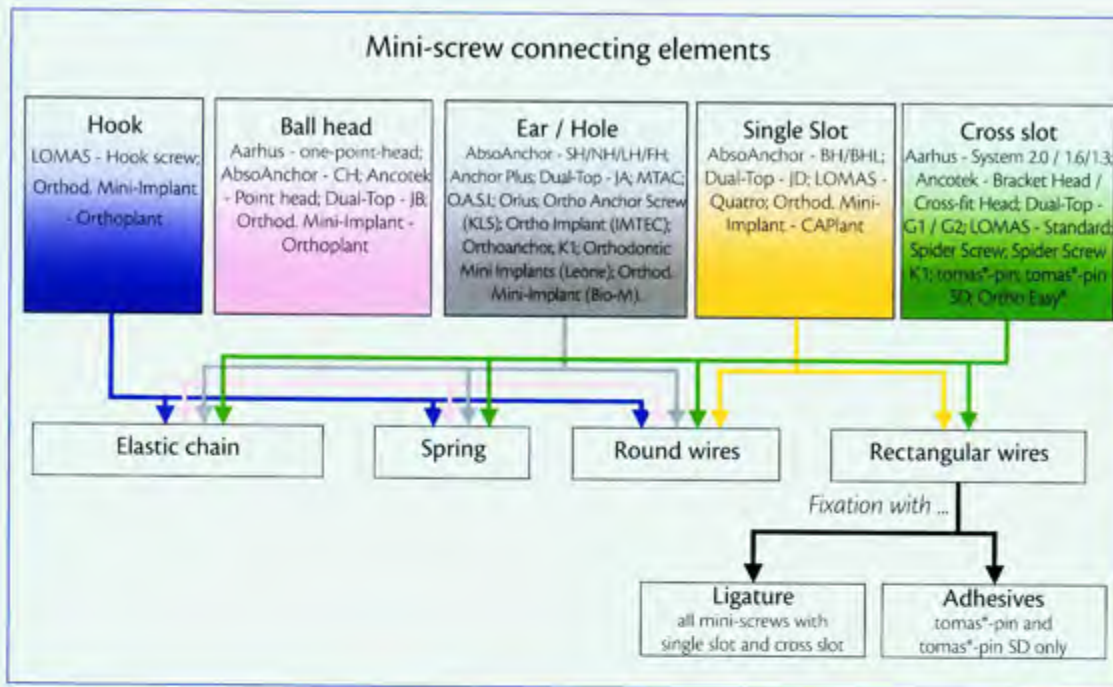


Fig. 3-33 The different kinds of screw heads and the connecting elements.

On the other hand, if the user inserts with the same effort used with a short screwdriver, the torque level rises dramatically. This could overstrain the bone or break the screw. Moreover, the tactile feeling for the bone is lost as well.

Almost all systems offer the possibility of mechanical insertion, as discussed in section 3.4.4. This requires a special angled handpiece to reduce the speed and torque applied to the mini-screw. Other types of handpieces that are not designed for this specific application should not be used.

All mini-screws that feature an integrated "depth stop" have a step transition or conical bench between the transgingival collar and the threaded shaft. With Aarhus-Mini-Implant, AbsoAnchor, Ancotek-screw, Orthodontic Mini Implants, Spider Screw and tomas®-pin, this depth stop is supposed to prevent overpenetration of the screw into the bone. As shown in section 3.3.4, a depth stop has some advantages; however, there still must be care to drive the screw only to this depth stop. If an attempt is made to drive these screws beyond the depth stop, then damage to the "tapped" or threaded bone support will ensue. To help to avoid this, the thickness of the gingiva must be measured before insertion of the screw. This distance should be correlated to the length of the transgingival collar to determine how far the screw should be inserted. On reaching that depth on the collar, insertion

should be discontinued^[1]. This is most important when using a handpiece to drive the screws as the tactile sensation of reaching the depth stop is often lost.

Position of the Screw Head

After an evaluation of experiences and failures with mini-screws, most manufacturers recommend that they should be placed within the attached gingiva. This alone is no guarantee for success or ideal function with a mini-screw. Design of the transgingival collar, the insertion technique, and the nature of the associated devices for driving the screw also have significant influence on survival rates.

3.5.3 Interconnection with Orthodontic Devices

After the successful insertion of the mini-screw, implant-supported mechanics may be initiated (Fig. 3-33). Round wires, square wires, springs, specially designed auxiliaries, and elastic chains can be used as connecting or coupling elements. The mini-screw can also serve as a direct or indirect anchorage. With direct anchorage, active connecting elements (elastic chains, springs, specially designed auxiliaries and also round wires) are directed from the mini-screw to the teeth selected for movement (Fig. 3-34).

Fig. 3-34 The direct connection between mini-screw and orthodontic appliance using an elastic "space closer" (photo: Prof. C. Morea, University of São Paulo).

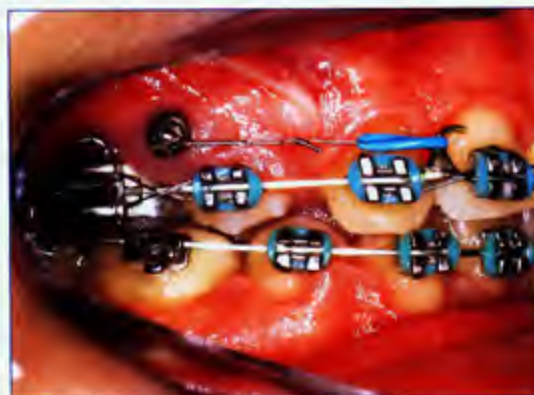


Fig. 3-35 The indirect connection between mini-screw and orthodontic appliance (photo: Prof. H. Wehrbein, Prof. M. Kunkel, University of Mainz).

Fig. 3-36 The fixation of a square wire with a ligature wire (picture: Jeil Medical/Promedia).



With indirect anchorage (Fig. 3-35), a supporting structure (square or rectangular wire segments) is constructed from the mini-screw to the dentition to prevent unwanted tooth movement. Müller-Hartwich et al¹²⁹ could not differentiate a difference in screw failure rate when comparing direct and indirect anchorage. There were, however, indications that micro-move-

ments of screws did occur when used as direct anchorage, especially when elastic chains and springs are employed. This may be the reason for disorder in bone remodeling, with a clinical consequence of often loosening the screw.

In section 3.3.2 the advantages and disadvantages of different head variations were discussed. As is evident from these remarks and Fig. 3-33, only mini-screws with a cross-slot can be connected with all types of connecting elements. Those screws that feature a cross-slot are suitable for all indications¹⁰⁶, especially if more than one type of connecting element is to be used at different points in treatment for a specific patient.

Cross-slot screws are also ideal for setting up indirect sectional mechanics (e.g. unilateral distalization using a segmented arch). In these circumstances, full fixed appliances may not be necessary, a truly esthetic alternative, or they may be required for a shorter period of time. Mini-screws with a cross-slot can perform as an excellent substitute for headgear. In this scenario, mini-screws are inserted between the maxillary first molars and second premolars. An orthodontic band or bond with a double or triple tube is placed on the first molar. A square wire is bent to permit insertion into one of the auxiliary tubes and also into the cross-slot of the mini-screw. This type of indirect or "base" anchorage can be used to support mesial, distal, intrusive, or extrusive movements, among other applications.

The connection of the mini-screw to different types of connecting elements should be simple and easy to perform, comfortable for the patient, and not limited by the insertion position of the screw. The fixation of springs, elastic chains, or round wires to most mini-screw systems is typically not a problem. Square wires can be easily fixed in place in the heads of screws with single or cross-slots. Apart from one exception, this may be accomplished using a ligature wire (Fig. 3-36). Depending on inserting position and screw design, this can be difficult (Fig. 3-37). In the product information on Aarhus-Mini-Implant, the picture with the fixation of the square wire (Fig. 3-38) suggests it may be simple, but the position of the screw in this example is not realistic.

An alternative to tying-in a square wire (i.e. wire ligation) into the cross-slot is to use light-cured bonding adhesive. This is a time-saving method of attaching wire segments that was first introduced with the tomas®-pin. Actually



Fig. 3-37 The steps to fixate a square wire with a ligature wire (picture: Jeil Medical/Pro-media).

many types of connecting elements may also be fixed in place with light-cured adhesive to the head of the tomas®-pin (Fig. 3-39) as it has a patented, circular intersection of the cross-slot into which the adhesive flows.

Immediate Loading

A significant advantage of mini-screws is that they may be loaded immediately after insertion. Mini-screws can be added and used immediately, especially when treatment plans may be changed mid-course and could substantially benefit from TAD-based anchorage. Immediate loading of mini-screws has been the subject of numerous investigations^{5,12,20,36,37,45,53,59,74,111,135}. Almost all of them came to the same conclusions – immediate loading is not only possible, but also it may positively affect the osseous density around the screw¹¹⁵. In contrast, *Ohmae* et al did not report any difference in the calcification of bone around screws that were immediately loaded or loaded later¹³¹. There appears to be no relationship between the particular design of a



Fig. 3-38 This picture suggests the connection is easy to handle, but the screw's position is not realistic (photo: Medicon).



Fig. 3-39 The head of the tomas®-pin has a patented undercut. Connecting elements, preferably square wires, can be fixed with a drop of light-cure adhesive (picture: Dentaaurum).

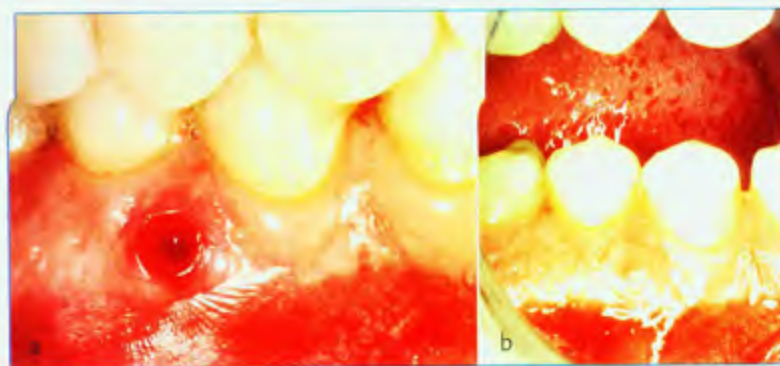


Fig. 3-40a and b Situation immediately after removal of the mini-screw (a). The gingiva heals without any special care after 48 hours (b):

mini-screw and whether it should be loaded immediately.

Most authors have suggested that screws should be loaded immediately after insertion, but some reports offered different conclusions. Recommendations have been made to wait 2 weeks^{26,88}, over 3 weeks⁴, and even up to 6 weeks before loading¹⁴. Woo et al¹⁰ reported a 20% failure rate for immediately loaded screws and 9% loss for those after a 7-day waiting period.

Opinions regarding the degree of force for immediate loading vary widely depending upon the design of the mini-screw employed with a spectrum from 10 cN¹⁷ up to 200 cN¹. Herman and Cope¹ recommend forces between 50 and 300 cN. According to Melsen¹¹, the load should not amount to more than 50 cN. Behrens and Wiechmann¹⁷ as well as Ohmae et al¹¹ see the limit at 150 cN. Liou et al⁸⁸ and Park et al¹⁰ recommend loads between 150 and 250 cN. Ohashi et al¹⁰ suggest a load between 30 and 250 cN. Finally, according to Büchter et al¹⁷ the load should not be more than 600 cN. The degree of loading has no apparent effect on the gingiva¹⁰⁹ and forces between 10 and 50 cN show minimal root resorption¹⁴. However, above 100 cN, the root resorption increases, and at over 300 cN, it is unacceptable.

3.5.4 Screw Removal

The largest stress for a mini-screw can be during its removal, not during insertion. For example, fractures of the AbsoAnchor described by Park et al¹⁰ are not primarily due to their small diameter (1.2 mm) and are not related to the bone-screw contact. Rather, it appears that the junction between the threaded shank and the neck may break¹¹⁰. Depending on the design

of the shank, there are differences in the torque required to unscrew a mini-screw²⁹. According to Chen et al²⁷ the screw removal torque is greater than 8.7 Ncm.

Despite the greater degree of torque required, all authors agree that removal of a mini-screw is quite simple and is often possible without anesthesia^{14,30,32,34,88,89,110,111,112,113,114,115}. Wound healing typically occurs within just a few days after removal (Fig. 3-40)¹⁴.

3.5.5 Rate of Success for Screws

There are numerous investigations that have reported failure rates of between 0% and 40% for mini-screws^{10,29,89,93,95,116}. Unfortunately, most of these studies are not directly comparable as the design and background of each may be drastically different¹¹⁷. Consequently, care must be exercised when using the results to draw conclusions about a specific screw system. For example, most of the reports never accounted for operator experience. Only a few studies have reported on a specific mini-screw system, such as the AbsoAnchor^{10,116}, Dual-Top® Anchor-Screw¹¹⁸ and tomas®-pin¹¹.

Factors influencing Mini-screw Success

Age/Gender

It seems that age and gender have no influence on the rate of success^{93,117,119}.

Anatomical Factors

The Angle Classification, the mandibular plane angle, the status of the TMJ, and the type of malocclusion appear to have no influence on the rate of mini-screw success^{93,117}.

Inserting Position (in General)

The position of insertion does not influence the rate of success^{117,118}.

Maxilla/Mandible

Park et al¹³⁵ reported a higher screw survival rate in the maxilla. Over-heating of bone during pre-drilling was given as a reason for more failures in the mandible. In contrast, Miyawaki et al¹¹⁷ found more success in the mandible than the maxilla.

Maxilla (According to Region)

Inserting mini-screws in the premolar region yielded the highest rate of success in the maxilla¹³⁵.

Right- and Left-hand Side

No substantial difference in screw success was reported whether it was inserted on the right or left side of the maxilla, although the left demonstrated a slightly better rate of survival¹³⁵. This presumably is linked with the level of oral hygiene, because right-handed persons mostly clean the left-hand side of the jaw more carefully than the right-hand side.

Thickness of Cortical Bone

The quality of primary stability for a mini-screw is directly related to thickness of the cortical bone. Primary stability is also the prime factor for a better survival rate^{76,80,117}.

Screw System

The type of mini-screw system appears to have no influence on the rate of success¹²¹.

Length of Screw

The length of the screw appears to have no significant influence on the rate of success^{90,117,135}.

Diameter of Screw

The diameter of the screw has no substantial influence on the rate of success^{90,135}.

Type of Insertion (Manual vs. Mechanical)

The kind of insertion (mechanical or manual) has no influence on the rate of success¹³⁵.

Competence of the User

As with any type of treatment, the experience of the user plays an important role for success. Inexperienced operators reported a 20% failure rate while those with more experience had 13% failures⁹².

Primary Stability/Mobility

A high primary stability reduces micro-movements of the mini-screw and improves healing^{75,80}. Screws that demonstrate some mobility (poorer primary stability) also have a higher rate of loss¹³⁵.

Contact with the Root

If a mini-screw makes contact with a root, some micro-movement will occur due to the mobility of a tooth that is under periodic load in normal function. This will increase the rate of loss

to 79.2%. During orthodontic tooth movement, it is certainly possible that teeth may be inadvertently moved into contact with an implant and cause premature loss. When mini-screws do not encounter a root, then the rate of survival is 91.7%^{12,88}.

Inflammation

Inflammation of the soft tissue around a mini-screw results in a greater rate of premature loss^{111,117,135}. Maintaining proper oral hygiene, especially immediately around the screw, is critical for success^{74,107,124}.

Connecting Elements

The type of connecting elements attached to a mini-screw has no influence on the rate of loss¹³⁵.

Type of Load: Direct or Indirect Anchorage

Using mini-screws for direct (Fig. 3-32) or indirect (Fig. 3-33) anchorage has no influence on the rate of success^{88,112,121}.

Local Stability

It is sometimes assumed that mini-screws are totally immobile and provide absolute anchorage. However, if we ignore Newton's Third Law (action = reaction), we do so at our own peril. Applying a (direct) load to a mini-screw must yield some type of counter-reaction. If suitable primary and secondary stability have been achieved, then the counter-reactive forces are absorbed within the structure of the supporting bone. If stability is less than ideal or too great a force is applied to the mini-screw, then the mini-screw may actually move within the bone. Liou et al have reported changes in mini-screw position from -1 to 1.5 mm¹⁰⁰. These changes are primarily tipping of the screw towards the load and can be seen clinically. Sometimes the investigation methods (i.e. measurement and evaluation on radiographs) that are chosen may be somewhat questionable. For example, Büchter et al found no changes in screw position^{19,21}.

3.5.6 Publications on the Description of Screws and Systems

The publications on clinical applications of mini-screws, mostly in the form of case reports, have increased since 1998 with a substantial increase in number since 2003. There have been literally hundreds of similar types of reports⁹⁴. In comparison, there are relatively few articles that describe a specific mini-screw system (Table 3-9).

Table 3-9 Articles (number in literature) that mainly describe only one mini-screw or system

Mini-screw name	Reference
Aarhus-Mini-Implant	115
AbsoAnchor	166
Anchor Plus/NeoAnchor Plus	No articles known
Ancotek	No articles known
Dual-Top Anchor Screw	54
LOMAS	No articles known
MTAC	No articles known
O.A.S.I.	No articles known
Orlus	No articles known
Ortho Anchor Screw	No articles known
Ortho Implant	38, 74
Orthoanchor	No articles known
Orthodontic Mini Implants	No articles known
Orthodontic Mini-Implant	No articles known
OSAS	No articles known
Spider Screw	106, 107
Ortho Easy®	In Press
tomas®-pin	22–24

4

3.6 Information from Manufacturers

In the previous sections, the most important aspects of design and application of mini-screws have been examined in a review of the contemporary scientific literature and general knowledge. This section will describe individual mini-screws in more detail. To provide an objective viewpoint and to give the reader some firsthand information, the manufacturers of the individual systems are referenced as well. As a result, all manufacturers who introduced mini-screw systems at the major international exhibitions and congresses (IDS, AAO, EOS, WFO and DGKFO) were given the opportunity to share information in this chapter. Presumably there are still some mini-screw manufacturers in Latin America and Asia (especially Eastern and South-East Asia) who were not represented at the previous meetings and do not currently distribute mini-screws in Europe and North America.

Questionnaires and Assessment

To provide easy comparisons for the consumer, a questionnaire (Appendix 3-01) was provided to each manufacturer in the summer of 2006. The questionnaire featured questions about the previously discussed aspects of mini-screws in four sections: general questions, design of the mini-screw, accessories for insertion, and applications of the device. As such, the reader should be able to quickly survey the factors or aspects that are of interest to them for each system.

Eighteen manufacturers were offered the survey and 12 responded (66% return). The following companies did not take part in the survey: Dentoflex (Brazil) – Dentoflex screw, American Orthodontics (USA) – MTAC screw, Lancer Orthodontics (USA) – OASI Implant, IMTEC Corporation (USA) – Ortho Implant, and Dentsply-Sankin (Japan) – Orthoanchor.

In Table 3-10, the actual responses of the 12 manufacturers are provided without comment. Contradictions in manufacturer's answers, in comparison to publicly accessible documents

(e.g. product information, internet websites, marketing materials) are not marked. Since all "self-drilling" screws are also "self-tapping", only one point was awarded for question B-09. Manufacturers who offer a self-drilling as well as self-tapping screw received 2 points. Question D-05 was determined to be ambiguous so that when answers were tabulated it was voided (blackened in the survey). The reader can evaluate the individual systems, comparing the results of the survey with the previous discussion of important aspects for mini-screws.

3.7 Summary

Temporary skeletal anchorage with mini-screws has been proven to provide reliable and successful results that are beneficial as part of routine orthodontic practice. The success of mini-screws seems to be primarily dependent upon the following factors: material used for screw fabrication, dimension and design of the screw, and the insertion technique. The components (e.g. insertion instruments) and auxiliaries determine if the mini-screw system will be successful and also "user-friendly". Obviously, many different mini-screws are currently available in the international marketplace and new products are constantly being introduced. It would seem important that specific criteria for their assessment should be defined. This will assist in the successful integration of mini-screw anchorage into routine use and as a standard of care for orthodontics. Therefore, using specific assessment criteria, the operator can make a better, informed decision when selecting a specific product for use with their patients.

The number of mini-screws in a specific system should be minimal. In principle, only three lengths (6, 8, and 10 mm) of the same diameter (1.6 mm) seem to be necessary for most clinical applications. Mini-screws shorter than 6 mm do not typically provide enough anchorage support due to the poor head/neck to shaft length (much like the crown to root ratio of a tooth). Mini-screws that are longer than 10 mm are not often required and considering the anatomical limitations of both jaws, they could be detrimental. In addition, stability of a mini-screw is generally determined by the thickness of the cortical plate, so screws longer than 10 mm seem redundant as the additional length provides for no additional stability

(unless bicortical anchorage is intended). Most often mini-screws are placed between roots of the teeth within the zone of attached gingiva. As a result, the diameter of a mini-screw should be as small as possible, but must be of sufficient dimension to support the forces of insertion, functional use, and subsequent removal. Titanium alloy (Ti4Al6V) requires a minimal dimension to withstand these forces. Therefore, a diameter of 1.6 mm seems to be good compromise to meet the anatomical and material-specific requirements for mini-screws.

The following list of favorable design characteristics for mini-screws was collated from the information presented previously:

- Head with cross-slot
- Diameter of the head should be equal to or smaller than the diameter of the transgingival collar/neck to avoid perimucositis or peri-implantitis
- Transgingival collar of conical shape with a length of about 2 mm permits a favorable soft tissue seal, free of inflammation
- Self-tapping or self-drilling thread with an ascent or rise of about 0.9 mm
- Cylindrical shank

As with any type of patient care, the risks, limitations, trauma, and pain accompanying treatment with mini-screws must be minimized. This also means that the rate of screw survival should be maximized. Many of the previously mentioned factors are important for success, but there are other aspects as well:

- Manufacturer pre-sterilized screws
- Profound topical anesthesia (at a minimum)
- Soft tissue punch
- Reduce forces to both bone and the mini-screw during insertion
- Manual insertion while maintaining constant low torque levels

After mini-screw insertion, orthodontic biomechanics may be immediately applied using any number of coupling devices or auxiliaries like square wires (for 3D control), round wires, elastic chains, springs, or other specific auxiliaries. This may include the application of forces to an orthodontic device or appliance, directly to individual teeth, or indirectly to groups of teeth to reinforce anchorage. The most often selected sites for mini-screw insertion are between the posterior teeth. Since this area is not as readily accessible, the application of coupling

Table 3-10

A - General Questions																																												
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A-02	Name of the investor:	H.-S. Park S.-M. Bae H.-M. Kyung	A-03	Name and location of manufacturer:	Dentax Inc. (South Korea)	A-04	Applied certification:	CE FDA other	A-05	Distributions in German-speaking countries:	Germany Austria Switzerland	A-06	Services offered:	Courses: De / En Collection of examples of use / case documentation: De / En Documents for patient information: De / En	A-07	Is the mini-implant fabricated from one piece?	yes	A-08	Which head designs are available?	hook-design (height / diameter in mm) ball-design (height / diameter in mm) loop-design (height / diameter in mm) single side (height / diameter in mm) cross slot (height / diameter in mm)	B-01	Design of the transosseous portion:	cylindrical (height / diameter in mm) conical (height / diameter in mm) rectangular (height / diameter in mm)	B-02	Does the thread continue to the mini-implant head?	no	B-03	Does the thread continue to the mini-implant head?	no	B-04	Does the thread continue to the mini-implant head?	no	B-05	Does the thread continue to the mini-implant head?	no	B-06	Does the thread continue to the mini-implant head?	no	B-07	Does the thread continue to the mini-implant head?	no	B-08	Does the thread continue to the mini-implant head?	no
A-02	Name of the investor:	H.-S. Park S.-M. Bae H.-M. Kyung	A-03	Name and location of manufacturer:	Dentax Inc. (South Korea)	A-04	Applied certification:	CE FDA other	A-05	Distributions in German-speaking countries:	Germany Austria Switzerland	A-06	Services offered:	Courses: De / En Collection of examples of use / case documentation: De / En Documents for patient information: De / En	A-07	Is the mini-implant fabricated from one piece?	yes	A-08	Which head designs are available?	hook-design (height / diameter in mm) ball-design (height / diameter in mm) loop-design (height / diameter in mm) single side (height / diameter in mm) cross slot (height / diameter in mm)	B-01	Design of the transosseous portion:	cylindrical (height / diameter in mm) conical (height / diameter in mm) rectangular (height / diameter in mm)	B-02	Does the thread continue to the mini-implant head?	no	B-03	Does the thread continue to the mini-implant head?	no	B-04	Does the thread continue to the mini-implant head?	no	B-05	Does the thread continue to the mini-implant head?	no	B-06	Does the thread continue to the mini-implant head?	no	B-07	Does the thread continue to the mini-implant head?	no	B-08	Does the thread continue to the mini-implant head?	no
A-02	Name of the investor:	H.-S. Park S.-M. Bae H.-M. Kyung	A-03	Name and location of manufacturer:	Dentax Inc. (South Korea)	A-04	Applied certification:	CE FDA other	A-05	Distributions in German-speaking countries:	Germany Austria Switzerland	A-06	Services offered:	Courses: De / En																														

devices must be easy, rapid, comfortable, and safe. When square or rectangular segmental or continuous wires are applied to mini-screws, light-cured adhesives can be used to fix the wires into slots within the heads of mini-screws that have been designed specifically for this purpose.

The success of treatment using mini-screw anchorage is primarily influenced by clinical factors and the experience of the operator. It is secondarily influenced by the design of the mini-screw and the components of the specific system. For this reason, several factors must be taken into consideration when selecting and utilizing mini-screws.

As can be seen from these extensive remarks, it is not easy for the clinician to compare and assess the different systems. Based on the literature and from personal clinical experiences, each user will have their own ideals or desires to fulfill when selecting a particular mini-screw system. Perhaps the clinician should prepare a list of questions or criteria that they wish to have fulfilled by a particular system (see Appendix 3-02). A checklist then permits easier comparison among available products and would facilitate the decision process for the busy clinician to select the mini-screw that is appropriate for optimal care for their patients.

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3.9 Appendices

Appendix 3-01

A – General Questions

1. Name of the mini-implant: _____
2. Name of the inventor: _____
3. Name and location of producer: _____
4. Available on the market since: _____
5. Applied certification: ☐ CE ☐ FDA ☐ others: _____

6. Distributors in German-speaking countries:

Germany: _____
 Austria: _____
 Switzerland: _____

7. Number of users world wide: ca. _____

8. Services offered?

Courses	☐ German	☐ English
Collection of examples of use/case documentation	☐ German	☐ English
Documents for patient information	☐ German	☐ English

B – Screw Design

1. Mini-implant material _____
2. Is the mini-implant fabricated from one piece? ☐ yes ☐ no
3. How many different mini-implant variations are available?
 _____ different lengths
 _____ different diameters
 _____ different head-designs
 _____ different versions altogether

4. Which head-designs are available?

☐ hook design	height: _____	diameter: _____	
☐ ball design	height: _____	diameter: _____	
☐ loop design	height: _____	diameter: _____	
☐ single slot	height: _____	diameter: _____	
☐ cross slot	height: _____	diameter: _____	

5. How is the mini-implant held in the insertion instrument?

☐ outside	(eg. hexagon)		
☐ inside	(eg. cross slot)		

6. Design of the transgingival portion:

☐ cylindrical	height: _____	diameter: _____	
☐ conical	height: _____	diameter: _____	
☐ hexagonal	height: _____	diameter: _____	

7. Relationship of max. diameter of collar and head:

☐ collar > head	
☐ collar = head	
☐ collar < head	

8. Does the thread continue to the mini-implant head?

☐ yes	☐ no	
------------------------------	-----------------------------	---

9. Design of mini-implant thread:

☐ cylindrical	☐ conical	☐ left-handed thread
☐ self-drilling	☐ self-tapping	

C – Accessories in the product range

1. Insertion site location aids:

☐ prefabricated wire element

☐ no device

☐ others: _____

2. Instruments to perforate the soft tissue prior to insertion:

☐ single-use gingiva-remover (punch)

☐ no instrument

☐ reusable gingiva-remover (punch)

3. Pilot drills:

☐ bur, to pre-drill/centring the bone

☐ no bur

☐ pilot bur with depth control

number of drills: _____

diameters: _____, _____, _____, _____

lengths: _____, _____, _____, _____

4. Instruments for manual insertion:

☐ long mini-implant driver

number of extensions: _____

☐ short mini-implant driver

number of variations: _____

☐ knurl

☐ ratchet:

☐ with ...

☐ without ...

torque control

5. Instruments for mechanical insertion:

number of instruments: _____

diameters: _____, _____, _____, _____

lengths: _____, _____, _____, _____

D – Application of the Mini-implant

1. Delivery of the mini-implant:

☐ sterile

☐ non-sterile:

Is there a recommendation for sterilization?

☐ yes

☐ no

2. What is the recommended maximum torque during the insertion? _____

3. At what torque would stress fracture occur? _____

How was the max. torque calculated?

☐ mathematical

☐ clinical

☐ experimental

4. How can the user control the torque during insertion?

5. Which elements can be connected to every head-design?

☐ round wires

☐ rectangular wires

☐ springs

☐ elastic chains

6. How can the connecting elements be fixed on the mini-implant?

☐ wire ligatures

☐ others: _____

☐ adhesive fixing

7. Are there published studies in regard to the mini-implant survival rate?

☐ yes

☐ no

8. Which steps are recommended to insert the mini-implant?

☐ topical anesthesia

☐ prepare a flap

☐ infiltration anesthesia

☐ gingival punch

☐ conduction anesthesia

☐ gingival incision

☐ no anesthesia

☐ screw through the gingiva directly

☐ pilot drill in the maxilla

☐ mechanical insertion

☐ pilot drill in the mandible

☐ manual insertion

Appendix 3-02

A – General Questions

1. Name of the mini-implant: Dual Top® Anchor Screw
2. Name of the inventor: Jeil Medical Corporation
3. Name and location of producer: Jeil medical Corporation/ Seoul, S.Korea
4. Available on the market since: 2002
5. Applied certification: ☒ CE ☒ FDA ☒ others: various
6. Distributors in German-speaking countries:

Germany: Promedia

Austria: Promedia

Switzerland: Promedia
7. Number of users world wide: ca. 150,000
8. Services offered?

Courses	☐ German	☒ English
Collection of examples of use/case documentation	☐ German	☒ English
Documents for patient information	☐ German	☒ English

B – Screw Design

1. Mini-implant material Titanium Alloy
2. Is the mini-implant fabricated from one piece? ☒ yes ☐ no
3. How many different mini-implant variations are available?

<u>3</u>	different lengths
<u>3</u>	different diameters
<u>5</u>	different head-designs
<u>5</u>	different versions altogether

4. Which head-designs are available?

☐ hook design	height:	diameter:	
☒ ball design	height: 2.5 mm	diameter: 1.4 mm	
☐ loop design	height:	diameter:	
☒ single slot	height: 2.1 mm	diameter: 2.7 mm	
☒ cross slot	height: 2.1 mm	diameter: 2.7 mm	

5. How is the mini-implant held in the insertion instrument?

☒ outside	(eg. hexagon)		
☒ inside	(eg. cross slot)		

6. Design of the transgingival portion:

☒ cylindrical	height: 0.7-1 mm	diameter: 1.4, 1.6, 2.0 mm	
☐ conical	height:	diameter:	
☐ hexagonal	height:	diameter:	

7. Relationship of max. diameter of collar and head:

☐ collar > head	
☐ collar = head	
☒ collar < head	

8. Does the thread continue to the mini-implant head?

☐ yes	☒ no	
------------------------------	--	---

9. Design of mini-implant thread:

☐ cylindrical	☒ conical	☐ left-handed thread
☒ self-drilling	☒ self-tapping	

C – Accessories in the product range

1. Insertion site location aids:

☐ prefabricated wire element

☒ no device

☐ others: _____

2. Instruments to perforate the soft tissue prior to insertion:

☐ single-use gingiva-remover (punch)

☒ no instrument

☐ reusable gingiva-remover (punch)

3. Pilot drills:

☐ bur, to pre-drill/centring the bone

☐ no bur

☒ pilot bur with depth control

number of drills: 1

diameters: 1.0 mm

lengths: 5.0 mm

4. Instruments for manual insertion:

☒ long mini-implant driver

number of extensions: 5

☐ short mini-implant driver

number of variations: _____

☐ knurl

☐ ratchet:

☐ with ...

☐ without ...

torque control

5. Instruments for mechanical insertion:

number of instruments: _____

diameters: _____

lengths: _____

D – Application of the Mini-implant

1. Delivery of the mini-implant:

☐ sterile

☒ non-sterile:

Is there a recommendation for sterilization?

☒ yes

☐ no

2. What is the recommended maximum torque during the insertion? 0.2 kg/cm

3. At what torque would stress fracture occur?

0.21 kg/cm for 01.4,

0.27-0.28 kg/cm for 01.6,

0.58-0.60 kg/cm for 0 2.0

How was the max. torque calculated?

☐ mathematical

☐ clinical

☒ experimental

4. How can the user control the torque during insertion?

—

5. Which elements can be connected to every head-design?

☒ round wires

☒ rectangular wires

☒ springs

☒ elastic chains

6. How can the connecting elements be fixed on the mini-implant?

☒ wire ligatures

☐ others: _____

☒ adhesive fixing

7. Are there published studies in regard to the mini-implant survival rate?

☒ yes

☐ no

8. Which steps are recommended to insert the mini-implant?

☒ topical anesthesia

☒ infiltration anesthesia

☐ conduction anesthesia

☐ no anesthesia

☐ pilot drill in the maxilla

☒ pilot drill in the mandible

☐ prepare a flap

☐ gingival punch

☐ gingival incision

☒ screw through the gingiva directly

☒ mechanical insertion

☒ manual insertion

Appendix 3-03

Example of a checklist with questions to evaluate a mini-screw system (from Bumann*):

Question 1:

How many different mini-screws come with your system?

Question 2:

Do you have self-tapping and self-drilling mini-screws?

Question 3:

What are the lengths of your mini-screws?

Question 4:

What are the diameters of your mini-screws?

Question 5:

What is the diameter of your pilot drill in relation to the outer diameter of your mini-screw?

Question 6:

Do you have different pilot drill diameters?

Question 7:

Do you have a torque-controlled ratchet to avoid breakage?

Question 8:

What is the torque moment at breakage?

Question 9:

What is the average removal torque for your mini-screws?

Question 10:

What is the height of the collar of your mini-screws?

Question 11:

Are your mini-screws pre-sterilized and do you fulfil all quality management criteria?

Question 12:

Does the mini-screw have a head in bracket design?

Question 13:

How do you fix the wire to the mini-screw, how safe is it and how long does it take?

Question 14:

What is the failure rate with your mini-screw system?

Question 15:

Which accessories are available for the mini-screw system?

* By courtesy of Prof. Dr. Axel Bumann (Berlin)

Insertion of Mini-screws

4.1 Preparation for Insertion of Mini-screws

The application of skeletal anchorage consists of two essential working steps: the insertion of the mini-screw and then coupling with orthodontic devices or biomechanics. Both steps should be carefully documented in the patient's file. In this chapter, the preparation and insertion process for mini-screws will be described.

The successful placement of a mini-screw is a basic condition to be able to use cortical anchorage in orthodontic mechanics. As was described in the previous chapter, different authors have formulated ideal requirements for skeletal anchorage^{13,15,21}. The majority of these requirements focus on the insertion process for the mini-screws. The following are factors that have a direct relationship to the success of the insertion of the temporary anchorage device:

- Small dimension (length and diameter) of the screw
- Easy positioning and insertion
- Primary stability
- Easy removal

This chapter may help the clinician with practical treatment planning with mini-screws: site selection, pre-operative diagnosis, anesthesia, and especially, the insertion process.

4.1.1 Pre-surgical Planning

When treatment planning includes the use of a temporary anchorage device, examination of typical orthodontic records (i.e. radiographs, models, photographs, and clinical examination) is a starting point. Selecting an applicable site where a mini-screw can be positioned safely (e.g. avoiding roots or "vital" structures)

may require a narrow focus. Since the application of orthodontic mechanics, appliances, and force systems is involved, a more substantial, global examination of the diagnostic records is also necessary. In other words, it is important to find a suitable location for successful insertion of the implant, but also to determine if that site will serve as appropriate anchorage for the intended tooth movements required by the specific malocclusion to be treated.

When the patient is first evaluated in a clinical examination, the basic anchorage requirements for the specific malocclusion can often be determined immediately. If mini-screws would improve the effectiveness, efficiency, or predictability of the desired biomechanics, then this concept can be introduced as a possibility to the patient.

After diagnostic records are taken, the desired position of a mini-screw can then be determined on the study models and intra-oral photographs. Next, the radiographs (i.e. panoramic and periapical "close-up" of a specific interradicular site) are examined to attempt to determine if that desired location has enough room for safe placement of the implant. A second set of photocopies of the intra-oral photographs are especially useful in treatment planning biomechanics. Drawing vectors and proposed mechanics on the photographs help the clinician determine the best location for the mini-screw for mechanical advantage. These drawings are also useful in consulting with patients and referring dentists.

For successful insertion with favorable primary stability of a mini-screw, there must be sufficient osseous density, cortical thickness, and distance between the roots of teeth. Typically, mini-screws are anchored monocortically although in some instances longer screws can be used for bicortical anchorage in the mandibular arch (i.e. the screw is driven through the buc-

Fig. 4-1 Monocortical anchorage.

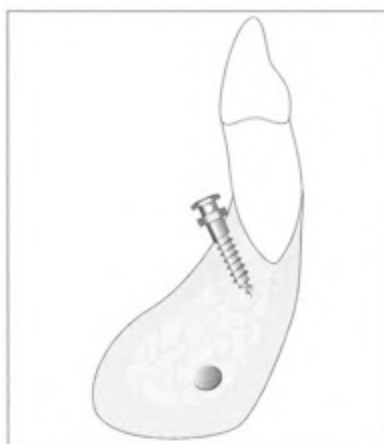


Fig. 4-2 Secondary stability of mini-screws: schematic illustration of post insertion time.

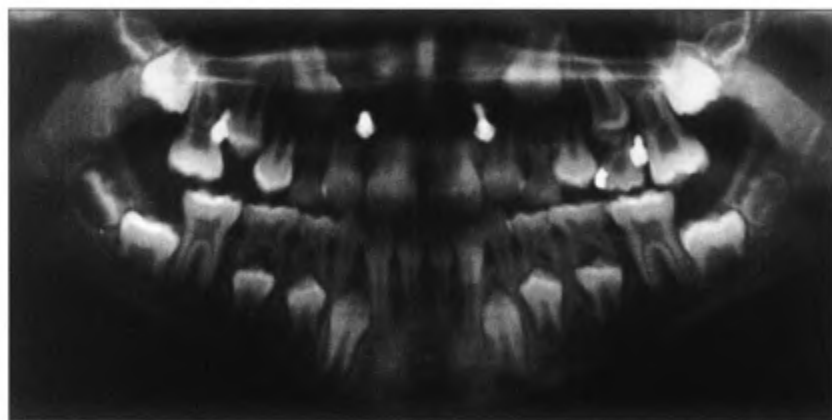
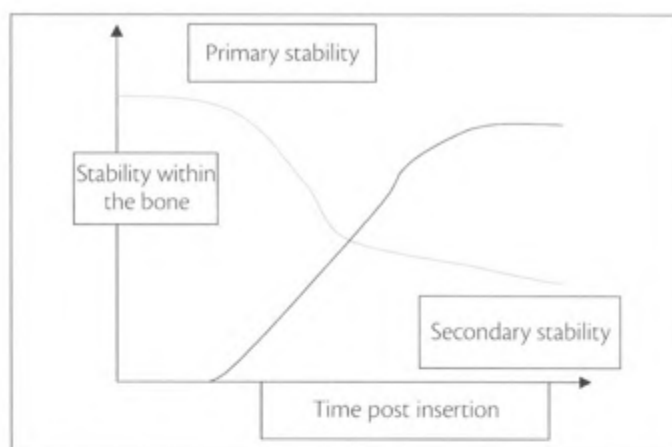


Fig. 4-3 Increased risk of loss of primary stability: insertion of mini-screws adjacent to dental follicles and deciduous teeth.

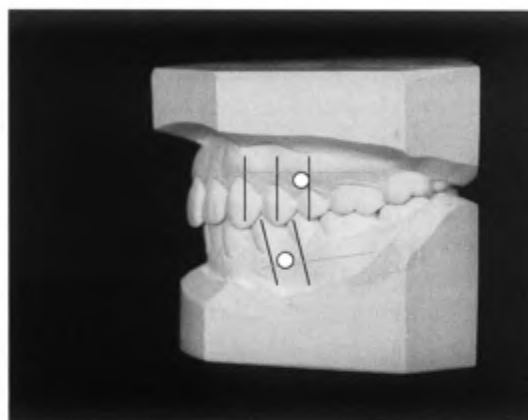


Fig. 4-4 Model of dental axes and position of mucogingival junction.



Fig. 4-5 Clinical picture of dental axes and position of mucogingival junction.

cal surface, and the tip of the screw will also be long enough upon complete insertion to penetrate the cortical bone on the lingual surface).

Monocortical anchorage indicates that anchorage with the mini-screw is derived primarily from the cortical bone only on one side of the alveolus (Fig. 4-1). Since cortical bone is typically only a few millimeters thick, it is critical that primary stability is realized; otherwise, premature loss or failure of the screw will result. As mini-screws are "non-osseointegrated implants", they are secured merely by mechanical retention of the threads and by the elastic capacity of the bone.

This primary stability of a mini-screw decreases after 4–6 weeks. Secondary stability, however, increases via osseo-conductive processes between the second and the third week (Fig. 4-2). The potential for actual osseointegration of mini-screws is controversial. Obviously, these screws are fabricated from titanium alloys that

are almost identical to their osseointegrated cousins used for prosthetic replacements. Despite the fact that mini-screws have a smaller diameter, the threads are highly polished, they are not "treated or coated" to promote integration and, consequently, have less surface area for bone contact; there still could be the possibility for osseointegration. In fact, some *intentional* osseointegration, to increase retention rates or stability, may yet find a place within the temporary anchorage arena in the future.

At the present time, we must focus on primary stability for success. As a result, the design of the mini-screw, the insertion technology, and clinical techniques are those factors that are most critical.

To achieve sufficient primary stability, good quality bone is the first requirement. The density and thickness of the maxilla and mandible are dependent upon the age of the patient, genetic factors, the specific insertion region and functional load. The density of the cortical bone and underlying spongiosa are different dependent in each jaw and in different locations within each jaw. For example, dramatic differences in bone quality and quantity can be observed between the anterior region in the mandible and the molar region in the maxilla. Caution is warranted when placing screws adjacent to dental follicles and deciduous teeth as there is more "spacious" bone architecture (Fig. 4-3). In areas where extractions have been performed, osseous regeneration should be permitted prior to inserting screws to ensure sufficient bone density. The thickness and density of the cortical bone is the single most important factor for primary stability of a mini-screw^{12,36}.

4.1.2 Model Analysis and Clinical Treatment Planning

Model Analysis

Selection of the site for mini-screw placement can be made on a diagnostic model of the patient's teeth. This location can be selected specifically on the basis of anatomy, apart from the practical application of biomechanics (another part of the decision process to be described later). In this process, two morphological parameters should be considered: the angulations (i.e. axes) of the teeth adjacent to the implant site and the location of the mucogingival junction.

Quite clearly, mini-screws should not be inserted into the roots. But there are other considerations in selecting an insertion site. If a mini-screw were to be placed apical to the mucogingival junction, within the unattached mucosa, complications from mechanical irritation, inflammation, and tissue overgrowth may result. These factors could also cause the implant to fail prematurely. Consequently, it is obvious that a mini-screw should be positioned "between the roots" and also is more likely to be successful if placed at or occlusal to the mucogingival junction.

When the dental axes and the position of the mucogingival junction are considered (Fig. 4-4) there is a restricted area where a mini-screw might be inserted. Poggio described these so-called "safe zones" for the insertion of mini-screws. The demarcations of these regions roughly agree with borders such as those defined diagrammatically in Fig. 4-4.

Schnelle et al³⁰ and Costa et al³¹ also examined the space relationship between the cemento-enamel junction (CEJ) and the mucogingival junction (MGJ). Therefore, when we consider the limitations of interradicular space along with the axes of teeth and the length of attached gingiva, there is a significantly restricted field for appropriate screw insertion – appropriate sites are limited.

Dental axes can often be determined by the course of *Jugae alveolariae* on the dental model. The length of the mucogingival junction can be measured intra-orally from the marginal edge of the gingiva with a common periodontal probe and this measurement can be transferred to the dental model as well.

Clinical Evaluation

Most often, the head of a mini-screw should lie within the attached gingiva to avoid risks for complications²⁵ (Fig. 4-5 and 4-6). In the mandible, the screw head is positioned below (or apical to) the mucogingival junction, and in the maxilla, the head is above (also apical to) the mucogingival junction.

The angulations of the teeth in the area where an implant is to be placed may also be determined clinically. The *Jugae alveolariae* or root prominence is often apparent or can be palpated to determine the axes of roots of adjacent teeth.

Fig. 4-6 Schematic illustration of mini-screw insertion: between dental axes and within the attached gingiva.

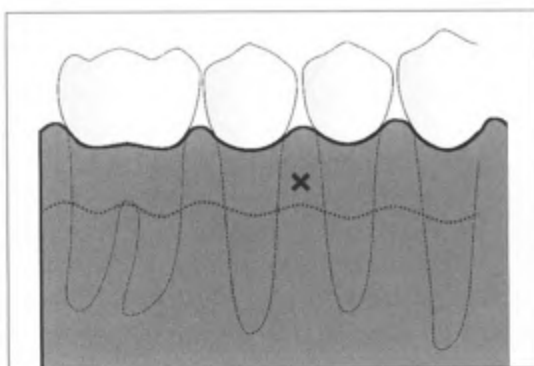


Fig. 4-7 Wire fixture as radio-opaque orientation device.

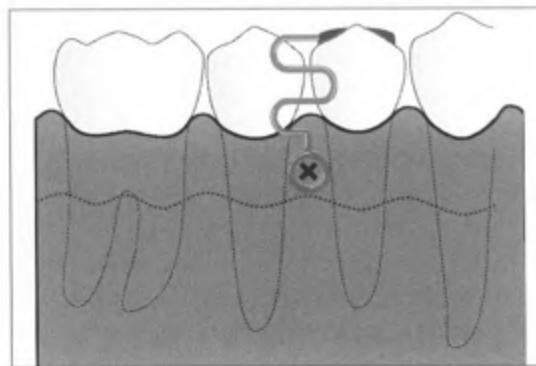


Fig. 4-8 "False positive" result of single-orientation film.



Fig. 4-9 Orthopantomogram as pre-operative radiograph (region of 45 and 46).

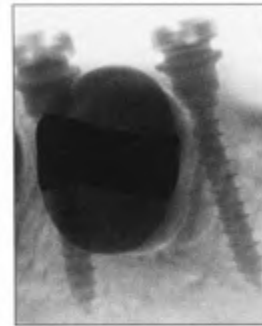


Fig. 4-10 Experimental three-dimensional radiograph of mini-screw insertion point.

Fig. 4-11 Employment of radiographic guide following control and identification of "positive" location.

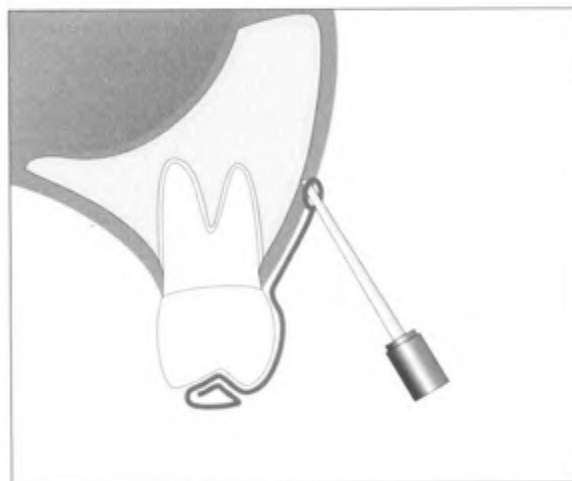
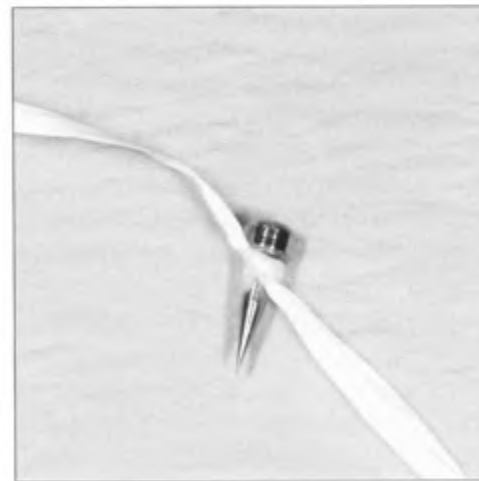


Fig. 4-12 Radio-opaque small orientation pins; tied with dental floss to facilitate retrieval.



4.1.3 X-ray Analysis

Radiographic examination prior to mini-screw placement assists in two ways: forensic safety and documentation. Radiographs provide a topographical survey of the relevant anatomical structures. At a minimum, some type of panoramic radiograph is required to estimate the bone quality, root angulations and proxim-

ity, position of "vital" anatomical structures (e.g. dental germs, nerves, vessels, sinus spaces). The screening nature of the panoramic film may lead the clinician to make additional or more detailed radiographic views (e.g. periapical, occlusal, or even CBCT) to more accurately determine if the implant site selection is safe.

A radio-opaque orientation device (e.g. stent or locator wire guide) may be positioned to



Fig. 4-13 and 4-14 Final mini-screw position above the mucogingival junction: controlled by radiograph.

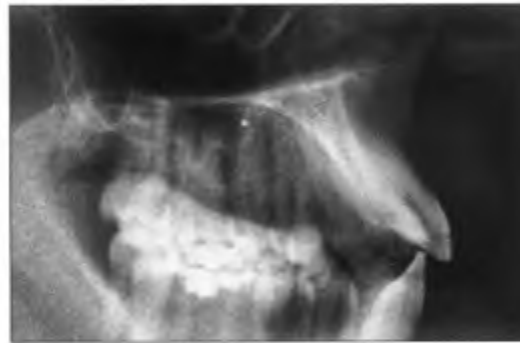
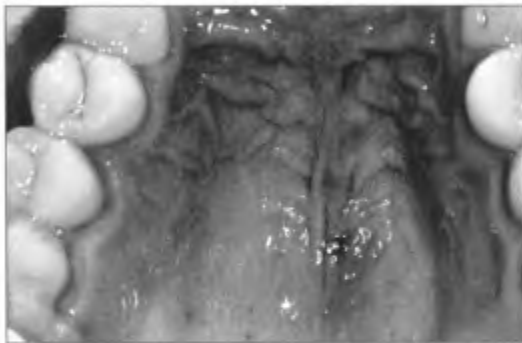


Fig. 4-15 and 4-16 Orientation pin in hard palate. The pre-operative X-ray indicates an inappropriate position for insertion. The arrow indicates a more suitable position.

locate an insertion site prior to taking a pre-surgical radiograph. These stents or guides are often fixed or keyed into the occlusal surfaces of the teeth or can be attached to the orthodontic wires or brackets if they have been previously applied^{14,18,21}. Often these wire fixtures are fastened temporarily with dental adhesives to the occlusal surfaces of teeth in the planned insertion location (Fig. 4-7). The subsequent periapical radiograph, taken with an appropriate paralleling technique, may help to better estimate an insertion position between roots. Unfortunately, distortions or errors in paralleling technique could produce “false positives” and a mini-screw could still be inserted into the wrong location (Fig. 4-8). Although there are still distortions, the panoramic film may provide fewer adjustment issues (Fig. 4-9).

Ideally, a three-dimensional radiograph (i.e. CBCT) is desired (Fig. 4-10). Unfortunately, access to and expense of these radiographic devices aside, the risk/benefit of routinely taking 3-D images for most instances of mini-screw insertion does not seem to make sense at this time. Further details on this issue will be discussed in Chapter 6. If a radiographic guide is

used and a “positive” location is noted, then the wire element or stent are used to mark the insertion point intra-orally (Fig. 4-11).

Alternatives to using wire locators or stents are small orientation pins (Fig. 4-12). These sterile implant analogues are pushed with light finger pressure into the gingival tissue (after appropriate local anesthesia) in the exact location where the mini-screw is to be inserted. This orientation pin is much like a tack or “push-pin” that is placed into a geographical wall map to mark a location. These radio-opaque pins should have dental floss tied around them so that they can be easily retrieved (and not swallowed) should they become dislodged. A radiograph is taken after the pin is in position to help to determine if the final mini-screw position is appropriate (Fig. 4-13 and 4-14). Stent construction, wire bending, or fixation to the occlusion or to an arch wire is not required when using the orientation pin.

The orientation pin may also be used in planning the insertion site for mini-screws in the hard palate (Fig. 4-15 and 4-16). In the example shown in Fig. 4-16 it appears that positioning the mini-screw more anteriorly may be more appropriate.

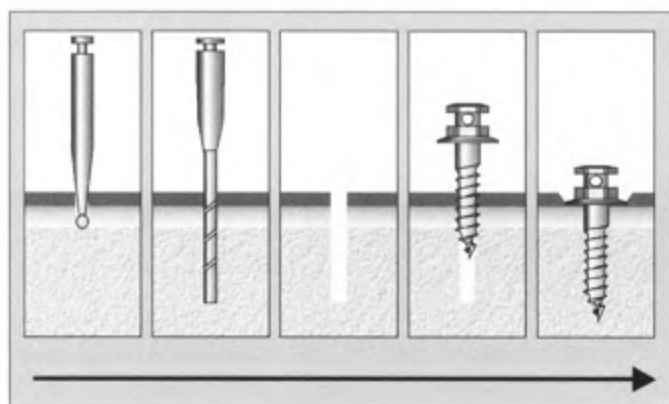


Fig. 4-17 Insertion process: self-cutting screws.

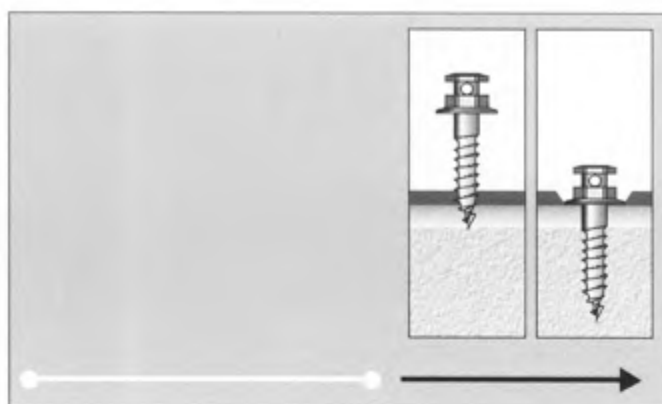


Fig. 4-18 Insertion process: self-drilling screws.

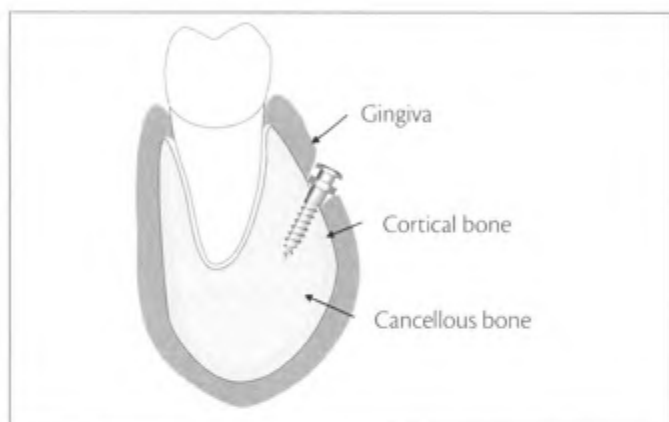


Fig. 4-19 Anatomical structures that interact with mini-screws.

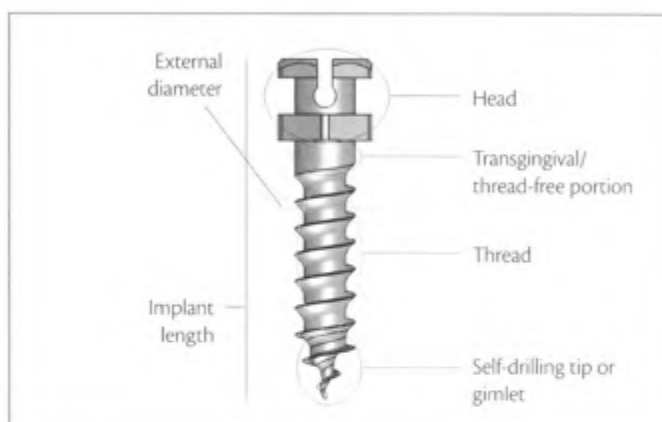


Fig. 4-20 Typical mini-screw design.

4.2 Procedure of Insertion of the Mini-screw/Pin

4.2.1 Self-cutting or Self-drilling?

Two variations of mini-screw systems have established themselves in the marketplace recently: self-cutting screws (Fig. 4-17) and self-drilling screws (Fig. 4-18). There are advantages and disadvantages to both types.

Self-cutting screws require pre-drilling and, as such, have more requirements for technical equipment.

Self-drilling screw systems do not demand a compulsory pre-drilling of the osseous base (although in some instances it may prove beneficial). The self-drilling screw works its way, depending on the form of the threads, through gingiva and cortical bone without the necessity of a pilot hole.

All manufacturers appear to now offer self-drilling mini-screws. Others (e.g. Spider Screw and tomas®-pin) also offer self-cutting variations. There is no evidence to indicate whether self-drilling or self-cutting screws have a better clinical prognosis²⁸. For regions with thin or less dense cortical bone structure, self-drilling screws are recommended. If, however, the cortical plate is quite dense or thick (e.g. mandibular alveolus of adult males), then pre-drilling a pilot hole for either a self-cutting or even a self-drilling hole is prudent.

The surgical expenditure and risk potential should be evaluated in each instance, a kind of risk/benefit analysis in determining the type of screw (self-drilling or cutting) to be used (see in addition the detailed explanations in Chapters 3 and 6). An important aim for the clinician is to keep the post-surgical burden for the patient low, to safely master the system selected, and to estimate the inherent risks objectively.



Fig. 4-21 Interradicular insertion of a mini-screw.



Fig. 4-22 and 4-23 Consideration of thickness of cortical bone prior to determination of insertion angle.

4.2.2 Choice of an Appropriate Mini-screw

When a mini-screw is inserted it penetrates three types of tissue:

- gingiva
- cortical bone
- spongiosa (cancellous) bone

These different tissues must be taken into consideration in the screw design and in the insertion technology (Fig. 4-19 and 4-20).

The screw head serves to enable the insertion of the implant and also the means for coupling it with orthodontic biomechanics. Therefore, the mini-screw must be placed in such a way that any selected appliances or force elements can be easily applied and yet be comfortable for the patient.

The design of the transgingival collar (the thread-free portion of the screw located just below the head) takes into consideration the anatomical characteristics of the gingiva. In other words, this part of the screw should help to avoid mucosal irritation, inflammation, or infection.

The threaded shaft of the mini-screw provides mechanical retention for primary stability. Self-cutting screws have a sharp, pointed tip (gimlet) that initiates the drilling advancement of the rest of the threads.

The external diameter of the threads of most mini-screws varies between 1.2 mm and 2.3 mm. The screw must be of sufficient structural diameter to resist breakage under load, yet narrow enough to fit into typical interradicular spaces. In addition, there must be sufficient cortical bone thickness for stability. Reports recommend from 0.5 mm¹⁷, over 1 mm²⁸, up to 2 mm¹⁶ of bone.

Since, the most frequent insertion site for mini-screws is between the roots of teeth (Fig. 4-21), the interradicular distance determines the maximum diameter of the screw. As a result, the position of the teeth, and their angulations both labio-lingually and mesio-distally determine the area of bone available between their roots where a mini-screw might be positioned.

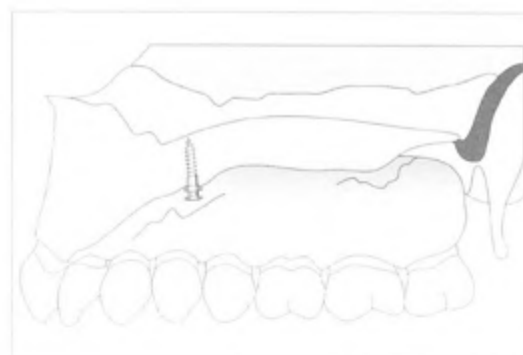
As a consequence of all of these contributing factors, it would seem that mini-screws with an external diameter of 1.6 mm might most often be selected.

The current marketplace is populated with mini-screws not only of varying diameter but also of extremes in length (from 4 mm up to 14 mm). As with the diameter, the choice of length of the appropriate screws depends on the bone available. Depending on the region, the thickness of alveolus may be between 4 mm and 16 mm (although the all-important cortical plate is a fraction of that width). Depending upon the direction of insertion (i.e. the insertion angle) of the mini-screw, it may penetrate more thickness of cortical bone (Fig. 4-22 and 4-23). Screws that are longer than 12 mm could lead to perforation of the other side of an alveolus especially on the lingual side of the anterior mandible or near the maxillary sinus (Fig. 4-24 and 4-25).

For the safe and effective retention of a mini-screw, its length is rather secondary – the diameter is much more important. The thickness of the cortical bone and contact area of the threads within that bone are more decisive parameters²⁷.

It is the thickness of the gingival tissues that is more critical in the choice of the length of a mini-screw: the thicker the tissue overlying the

Fig. 4-24 and 4-25 Feasible mini-screw perforation (lingual side of the anterior mandible or, as depicted, near the maxillary sinus).



alveolus, the longer the screw that is required. For instance, the tissue in the posterior palate and in the retromolar areas may be more than 4 mm in thickness. Although these are rare insertion locations, longer screws are required to provide the 6 mm of bone anchorage that is recommended for adequate stability. Consequently, at least a 10 mm long mini-screw is often required in these areas.

Poggio et al.¹⁸ recommend mini-screws of lengths from 6 to 8 mm. Costa¹⁹ concurred with these findings. It appears that for the majority of applications, longer screws are rarely needed. Therefore, only screws with lengths of from 6 to 10 mm are suggested. Based on anecdotal clinical observations, Axel Bumann and Jay Bowman have both suggested that although 6 mm screws would probably be sufficient for most routine biomechanics, they often just use 8 mm screws to simplify inventory. Selections of screws by color-coding, such as with the Ormco Vector system, therefore seems superfluous.

The head of a mini-screw should be easily adaptable to nearly any type of desired biomechanics that could benefit from temporary anchorage. Therefore, coupling devices, auxiliaries, and appliances should be simple and as universal as possible. In addition, if changes in biomechanics become necessary during treatment, then changes in orthodontic elements attached to the screws should be simple as well. Consequently, the clinician must choose a screw design that best fits his treatment philosophy and the types of orthodontic mechanics that he or she wishes to employ (further details in Chapters 3 and 5).

To reduce inventory and simplify clinical practice, it seems logical that only mini-screws featuring a multi-functional head might be kept in stock.

The important aspects in selecting an appropriate screw:

Diameter	Length	Screw head
↓	↓	↓
approx. 1.6 mm	6–10 mm	universally coupleable

4.2.3 Instruments and Insertion Preparation

Depending on the type of screw used (i.e. self-cutting or self-drilling), different instruments are required. The following checklist of instruments is provided in the chronological order in which they may be employed during mini-screw insertion.

Instrument Checklist

- a) General armamentarium
 - Basic set of dental instruments (Fig. 4-26)
 - Sterile tray cover (Fig. 4-27)
 - Sterile suction tips (Fig. 4-28)
 - Anesthesia: local and/or topical gel (Fig. 4-29)
- b) Instruments for "self-cutting" mini-screws
 - mucosal "biopsy or soft-tissue" punch (Fig. 4-30)
 - Rotary drill (Fig. 4-31)
 - Pilot drill (Fig. 4-32)
 - Elbow or contra-angle surgical handpiece (Fig. 4-33 and 4-34)
 - Hand driver or dental handpiece driver for the mini-screw (Fig. 4-35 to 4-37)
- c) Instruments for "self-drilling and self-cutting" screws
 - Hand driver or dental handpiece driver for the mini-screw (Fig. 4-35 to 4-37)

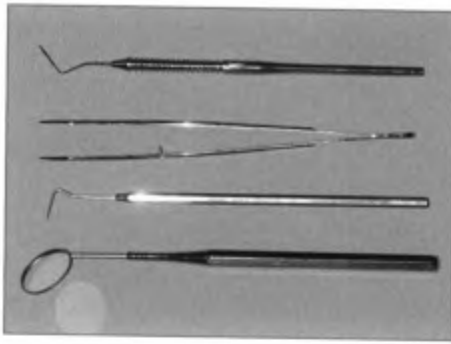


Fig. 4-26 Basic set of dental instruments (mirror, dental probe, forceps, periodontal probe).



Fig. 4-27 Sterile tray cover (single use).

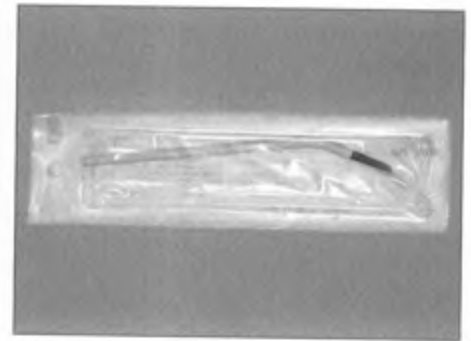


Fig. 4-28 Sterile suction tip (single use).



Fig. 4-29 Anesthesia (local and/or topical gel).

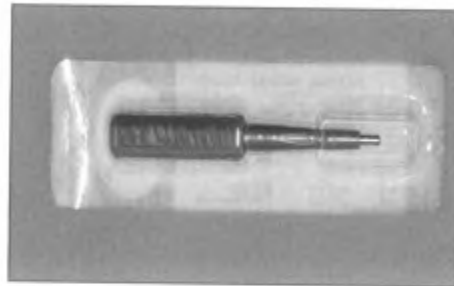


Fig. 4-30 Mucosal "biopsy or soft-tissue" punch.

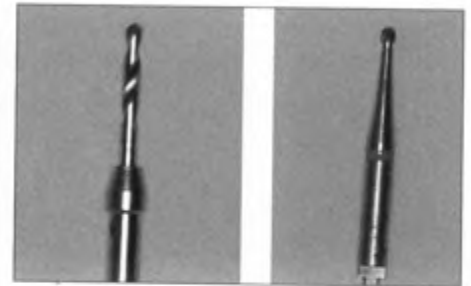


Fig. 4-31 and 4-32 Pilot and rotary drill.



Fig. 4-33 Angled surgical handpiece for mechanical insertion and pre-drilling.



Fig. 4-34 Contra-angle surgical handpiece with sterile NaCl solution.



Fig. 4-35 Hand driver in two sizes for mechanical insertion and blades in various lengths; the latter are complementary with contra-angle handpiece.

The clinician has the option of purchasing either non-sterile or pre-sterilized mini-screws from many manufacturers. Non-sterile screws must be sterilized in-office (Fig. 4-38 and 4-39). See also section 3.5.1. Manufacturers may offer sterilization racks into which the screws and other instruments are placed for sterile processing. Many of these racks offer separate sections for different screw dimensions and screw types.

Screws that are pre-sterilized by the manufacturer are delivered in sterile, sealed packaging

and can be used immediately without further in-office processing procedures, time and costs (Fig. 4-40 and 4-41).

No matter which types of mini-screws are used, minimum requirements must be met for sterile insertion of these screws even though this is a minimally invasive procedure. Consequently, the workplace (specifically the operator and associated armamentarium) must be prepared accordingly to reduce the risk of inadvertent infection.



Fig. 4-36 and 4-37 Torque ratchet with adjustable torque and rigid handpiece for manual insertion.



Fig. 4-38 and 4-39 Re-usable sterilization racks in various sizes and sealed in protective film with manufacturing date. Double-sealed products comply with sterilization guidelines for a period of up to 5 years.



Fig. 4-40 and 4-41 Pre-sterilized screw supplied in sealed packaging and ready to use.



Fig. 4-42 Topical anesthetic with gel.

4.2.4 Insertion of the Mini-screws/Pins Step-by-Step

4.2.4.1 Anesthesia

Prior to the initiation of local anesthesia, the oral cavity should be thoroughly rinsed with 15 ml of 0.12% chlorhexidine gluconate to reduce the intra-oral bacterial flora.

Topical anesthetics are often sufficient for the placement of mini-screws in most instances. The delivery of a topical anesthetic is not intimidating to patients and they are often surprised at their effectiveness in eliminating any pain during the brief insertion of these tiny screws (Fig. 4-42). Most commonly used topical anesthetics are either applied as gels or creams: TAC 20% Alternate topical anesthetic (20% lidocaine, 4% tetracaine, and 2% phenylephrine; Professional Arts Pharmacy, Lafayette, LA); EMLA, a highly profound topical cream (AstraZeneca, Wilmington, DE) that is a eutectic mixture of 2.5% lidocaine and 2.5% prilocaine; DepBlu (Steven's Pharmacy, Costa Mesa, CA), a compound of 10% lidocaine, 10% prilocaine, and 4% tetra-

caine; or Oraqix (2.5% lidocaine; 2.5% prilocaine; Dentsply Prof., York, PA), which is a gel that is delivered in a needle-free applicator.

The soft tissue at the intended implant site should be dried with a 2" x 2" cotton gauze. About 1 g of the topical material is applied directly to the soft tissue using a cotton swab applicator. The anesthetic is left in place for no longer than 2–4 minutes before thoroughly rinsing to avoid any soft tissue irritation or surface epithelial sloughing. These topicals typically provide for a more than sufficient 30-minute working time of anesthesia.

Isolation methods such as lip retractors, cotton rolls, and suction may be employed as necessary to reduce site contamination and provide a clear working field. A povidone-iodine topical antiseptic (Betadine, Purud Pharma, Stamford, CT) may be also applied to the tissue, just prior to insertion of the screw.

Although the majority of mini-screws may be placed using only a topical anesthetic, it might be wise to have a dental syringe prepared for use as needed (e.g. 2% lidocaine with

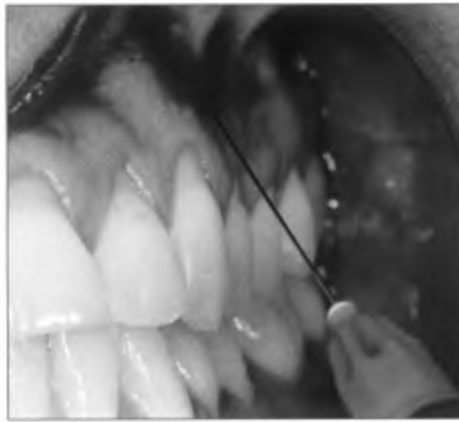
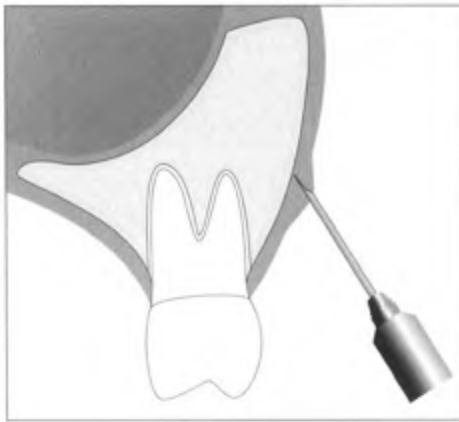


Fig. 4-43 and 4-44 Infiltration anesthetic at required position (maxilla).

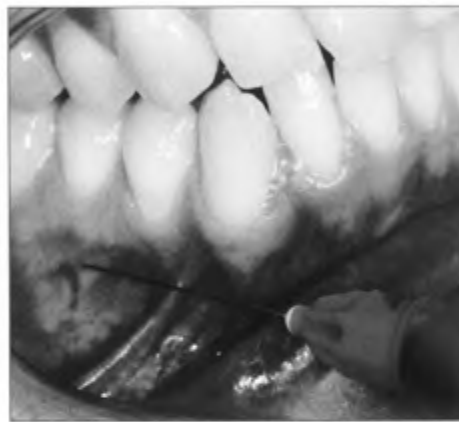


Fig. 4-45 and 4-46 Infiltration anesthetic at required position (mandible).

1:100,000 epinephrine). This implies that appropriate needle-capping techniques (e.g. one-handed "scoop" or two-handed with an appropriate barrier), aspiration methods, and needle disposal protocol will be followed (Fig. 4-43 to 4-46). The needle should be inserted adjacent to the location where the implant is to be placed and not in the depth of the vestibule. The typical "block" anesthesia is not necessary in all but the most extreme situations or if an implant is to be placed in some areas of the palate.

4.2.4.2 Measurement of the Gingival Thickness

The typical thickness of the gingiva is about 1.25 mm according to Goaslind et al¹². Costa et al⁶ reported gingival depth of between 1.4 and 4.2 mm depending on the specific region. The most frequent insertion point for mini-screws in either jaw is between the first molar and second premolar, where the typical thickness of gingiva is between 1 and 2 mm. The thickness of the gingiva is easily measured by inserting a periodontal probe or root canal instrument

into the anesthetized tissue. However, this typically makes sense only in the border regions (retromolar or in posterior palate) because the variation in gingival thickness in other areas is so small that it seems to be an unnecessary and added step.

4.2.4.3 Tissue Punch

The first barrier that must be overcome in placement of a mini-screw is insertion through the gingiva. If using self-cutting screws, then pre-drilling a pilot hole is compulsory. Without first perforating the gingiva, the mucosa may "roll-up" the pilot drill, resulting in tearing of this friable tissue. Therefore, the gingiva (either attached gingiva or mucosa) should be perforated with a sterile tissue or biopsy "hole" punch (Fig. 4-30). The circle of tissue that is cut by the sharp punch must then be removed from the surface of the alveolus with sterile tweezers or a sharp surgical spoon (Fig. 4-47 and 4-48). If the tissue is torn or ragged, it may develop an infection or inflammation; either of which



Fig. 4-47 and 4-48 Sharp tissue punch in the region of the mucogingival junction.

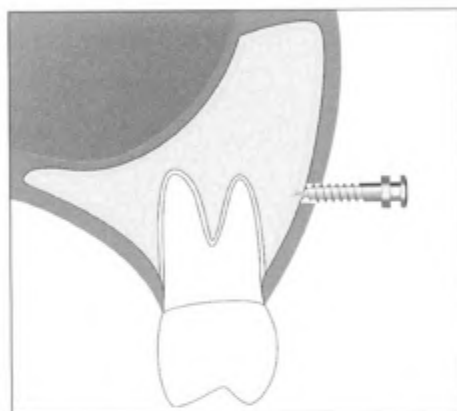


Fig. 4-49 Gingival perforation with self-drilling screw.



Fig. 4-50 Pre-drilling with rotary drill.



Fig. 4-51 Pilot drill.

Fig. 4-52a Manual insertion of mini-screw.

would likely result in subsequent failure of a mini-screw.

For many situations where "self-drilling" mini-screws are selected, using the soft tissue punch may still be recommended, especially if the screw is to be placed within the unattached mucosa or in regions where dense cortical bone might require a pilot hole (e.g. posterior mandible of adult males). In most cases, self-drilling mini-screws serve as their own tissue perforation device. It is important to press the self-drilling screw through the gingiva direct to osseous contact (Fig. 4-49). Turning the screw should be avoided during this initial pen-

etration of the tissue as it may lead to soft tissue injuries and provide a means whereby basal cells are accumulated along the threads and then driven into the alveolus. This could lead to a peri-implantitis and premature loss (see also section 3.5.2).

4.2.4.4 Bone Indentation and Pilot Drill

A self-drilling mini-screw or pilot drill could slip or skip along the surface of alveolar bone during the initial stages of implant insertion. Adjacent tissue could be torn as a result. The risk is higher when a pilot drill or self-drilling screw is

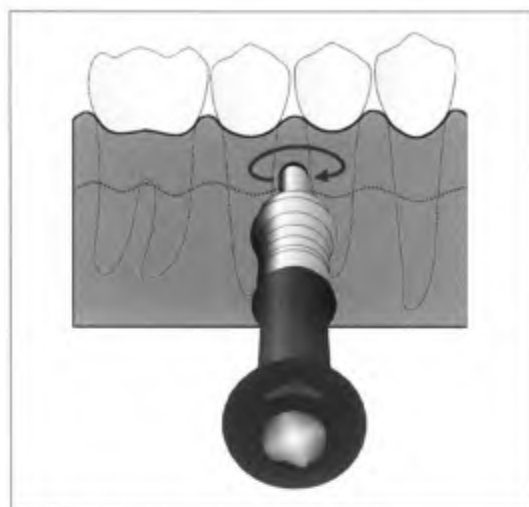


Fig. 4-52b Manual insertion of a mini-screw.

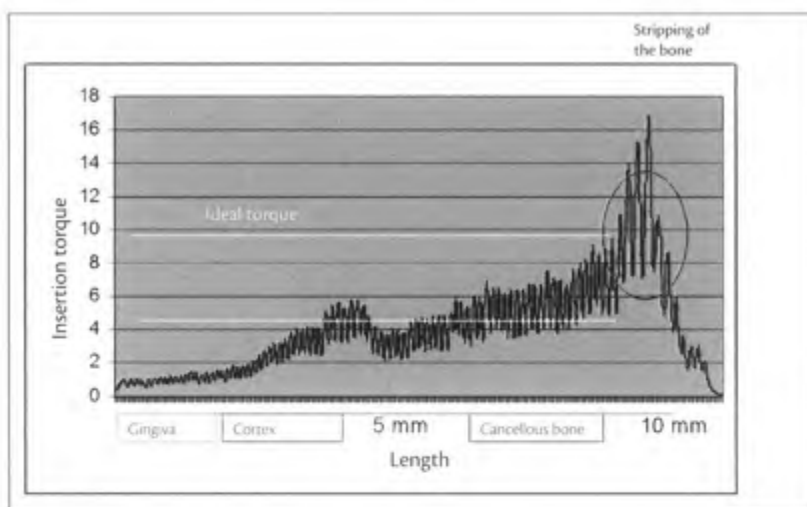


Fig. 4-53 Graph of manual insertion with a hand driver.

inserted at an angle to the surface of alveolar bone (as most are). Therefore, it might be helpful to drill a small indentation into the surface of the bone with a small round bur to give a purchase point for the tip of either the pilot drill or a self-drilling screw (Fig. 4-50 and 4-51).

If drilling a pilot hole is required, then the length and diameter of the pilot drill are critical aspects. If, for example, the external diameter of a pilot drill and the mini-screw threads are the same, the screw will likely fail⁹. Hence, the external diameter of the screw must be smaller than the corresponding pilot drill. It is for this reason that specific pilot drills are typically offered by manufacturers to accompany their screws. The difference in the diameter between drill and screw typically varies between 0.3 and 0.7 mm^{14,20}.

Gantous and *Phillips* recommend a gimlet diameter of between 70% and 85% of the screw diameter¹⁰.

The length of the drill is based on the length of the screw but a special drill is not required for every screw length; in fact, drills often have a depth mark on the working part. In addition, drills that feature a depth stop are preferred as they help to avoid unintentionally over-penetrating bone.

Some mini-screw systems feature drills with different gimlets and, as such, they should be marked unambiguously. Pre-drilling should minimally traumatize the bone; therefore the maximum speed should be from 500 to 1500 rpm. Cooling with sterile saline helps to reduce over-

heating the bone. Finally, a drill should be used for only one pilot hole before thorough cleaning and sterilization. In addition, the drill should be used to penetrate the pilot hole only once. It should not be reinserted as this, too, may introduce tissue into the hole and increase the risk of infection or premature loss of the screw.

4.2.4.5 Manual Insertion of Mini-screws/Pins

Manual insertion or driving is the easiest and most frequently practiced method for placing mini-screws. The procedure most often requires the use of a large screwdriver or hex wrench (Fig. 4-52b).

The technique or method of insertion plays a significant role in the final result. The screw must be inserted with the application of low and steady torque, limited lateral movements, continuous pressure, and at a maximum of 30 rpm. Torque variations and intermittent rotary movement (e.g. changing the axis of rotation or "wiggling" the driver) will deflect the osseous base and can negatively affect the primary stability. In addition, strong mechanical loads may increase the risk of fracturing the screw.

The process of manual insertion with a hand driver is shown in Fig. 4-53. A constantly applied torque of 4–10 Ncm (without significant variation) is ideal to drive the mini-screw. If more torque than that is required to advance the screw (i.e. the screw is over-turned), then the screw could be broken or the osseous base destroyed (the bone is "stripped" or augured-out).

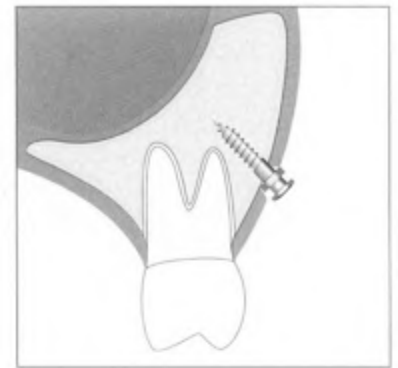
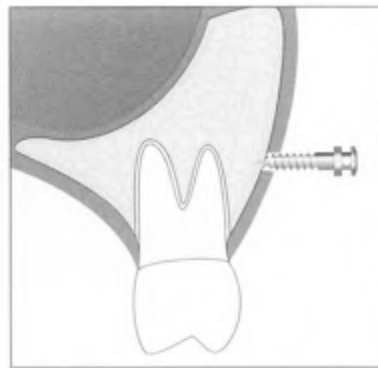


Fig. 4-54 to 4-56 Manual insertion (maxilla) at 90° and 45°.

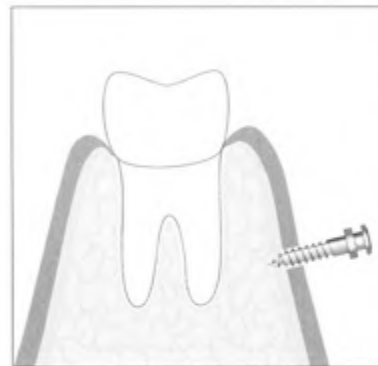


Fig. 4-57 to 4-59 Manual insertion (mandible) at 90° and 45°.

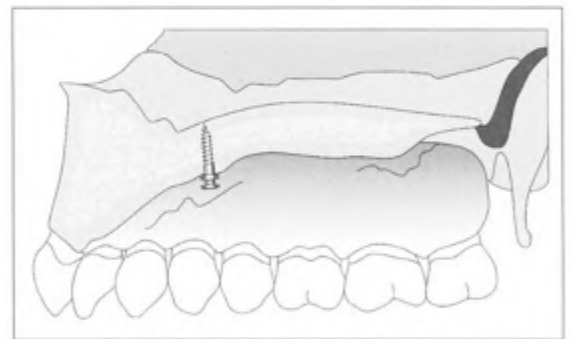
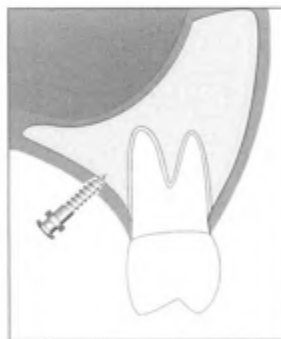


Fig. 4-60 to 4-62 Manual insertion (maxilla). Clinical case in median region; paramedian region as schematic illustration to demonstrate space implications.

The tactile sense of resistance from the hand driver often assists the clinician in determining the quality and quantity of the cortical bone. If the screw pushes through the cortical plate like an egg-shell, the likelihood of implant success is low. If, on the other hand, resistance at the surface is substantial, then perhaps pre-drilling a pilot hole could prevent a fractured screw.

It is important that torquing forces generated by the hand driver be minimized to avoid

fracture. The hand and wrist should be fixed with the handle of the driver abutted against the palm. Turning the screw should not be done with the wrist as the forces created are too large. Instead, the mini-screw should be twisted only with the thumb and forefinger.

After the mini-screw has been inserted, the removal of the driver must be done carefully to avoid unintentional widening of the hole, breakage of the screw, or damage to the threaded cortical bone.



Fig. 4-63 and 4-64 Mechanical insertion (maxilla); contra-angle handpiece with minimized torque.

The heads of some mini-screws have a simple slot or cross-slot. The orientation of these slots may still be visible during insertion with some systems (i.e. with the driver on the screw). If the slot is not visible, then some type of mark on the driver may indicate the orientation. Insuring the proper position of these slots is critical in some applications as wire segments or auxiliaries may require a specific slot orientation.

Screws can be inserted at a 90° angle (perpendicular to the alveolus) or at more acute angulations, e.g. 45° (Fig. 4-54 to 4-59). It is easier to "start" and insert a mini-screw at a 90° angle as the screw head is ideally positioned for the application of torque using the driver. It is also most often easier to attach auxiliaries or segmental mechanics to the head of the screw.

Unfortunately, there is also less cortical bone compared to an angulated insertion and there is also less space between roots when screws are placed in this manner in some instances. If, on the other hand, screws are placed at a more acute angle towards the apex of the teeth, then the threaded shaft of the screw has more bone available, especially since the roots tend to narrow towards their apices.

If mini-screws are to be inserted into the hard palate then there must be some special consideration given for amount of bone available and the anatomical structures within this region (e.g. vascular bundles and fasciculi) (see Chapter 6). Since access for a straight hand driver is limited by the patient's ability to open their mouth wide enough, an alternative means for driving mini-screws in the palate is required. Consequently, a short-handle driver, ratchet-wrench driver or contra-angle handpiece driver may be preferable (Fig. 4-60 to 4-62).

4.2.4.6 Inserting Mini-screws with a Dental Handpiece

In order to use a dental handpiece for insertion of mini-screws, a special "elbow" or contra-angle with gear-reduction is required. In addition, the handpiece must be adjustable to produce very slow rotational speeds of about 25 rpm along with limited torque (Fig. 4-63 and 4-64). These types of handpieces are often used in the surgical placement of dental implants.

Mini-screws are inserted with continuous torque with these handpieces. Therefore, the applied load is steady for both the bone and screw. Peaks in torque that occur when driving screws by hand are avoided. Handpieces that do not permit adjustment in rotational speed and torque levels are contraindicated. An important disadvantage of machine insertion is that there is reduced tactile feeling for the resistance of bone and the load on the screw. This is very important if a root is inadvertently encountered during screw insertion. With a hand driver, the force level may dramatically increase as resistance is encountered. With a handpiece, the clinician may not feel that resistance and the screw could be driven further, thereby damaging the root.

4.3 Post-operative Phase

4.3.1 Healing Phase

After successful insertion, the mini-screw is ready to be used as anchorage for orthodontic biomechanics. The position of the screw head and favorable primary stability should be verified before coupling or attaching forces or appliances (Fig. 4-65 to 4-67). It may have

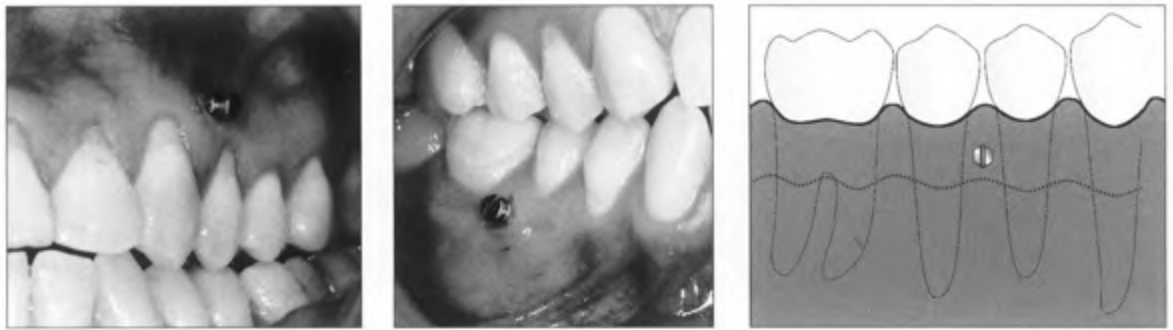


Fig. 4-65 to 4-67 Position of screw head in the region of attached gingiva post-insertion.



Fig. 4-68 Degree of compression: no pressure in the region of hard palate post-insertion.

been necessary to appropriately orient the head of the screw slightly. As a result the degree of compression of the gingiva should also be assessed (Fig. 4-68). If the screw appears loose (poor primary stability), it should be removed, a new site should be selected and another screw placed. Secondary stability is extremely unlikely with mini-screws; therefore, the loose screw will fail.

The initial retention of a mini-screw (also true for prosthetic implants) is reached immediately after insertion by purely mechanical anchorage. This is a result of a combination of displacement and compression of the surrounding bone.

One significant advantage of using mini-screws for skeletal anchorage for orthodontics compared to dental implants or plates is that they may be loaded immediately after placement. This is no reason to wait for osseointegration as it is unlikely to occur. The immediate loading of mini-screws has been the sub-

ject of many investigations^{1,11,19}. Nearly all reported the same findings: the immediate loading capacity of mini-screws is successful and is sufficient for orthodontic anchorage. In addition, the immediate loading of bone also favorably improves the osseous density immediately adjacent to the mini-screw²⁰.

4.3.2 Explantation of Mini-screws

Depending on the shaft design, there are differences in the amount of torque required to unscrew or remove the screw¹. However, researchers have agreed that removing mini-screws is typically uneventful and often possible without anesthesia^{5,8,27,31}.

Since most hand drivers are fixed to the head of the mini-screw during the removal process (unscrewing or counter-clockwise rotation: "righty-tighty; lefty-loosey"), this helps



Fig. 4-69 to 4-73 Healing phase of four subsequent days following successful explantation.

prevent the screw from slipping off and into the pharyngeal space. After removal, the small mucosal wound or hole that remains will quickly heal in a few days (Fig. 4-69 to 4-73).

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Fields of Application of Mini-Implants

In this chapter, various possibilities for clinical mini-implant applications are demonstrated. Due to the large variety of insertion sites for mini-implants, there is a bigger spectrum of indications than for the other skeletal anchorage options.

Before the different treatment options with mini-implant anchorage can be discussed, an explanation of how to couple the mini-implant to the orthodontic appliance (direct versus indirect anchorage) is required. As such, the mechanics of mini-implant anchorage should be an integral part of the orthodontic treatment planning process.

5.1 Direct versus Indirect Anchorage

In general, two different types of anchorage must be distinguished: direct and indirect. Determining the type of anchorage that is more favorable depends on the following clinical or radiological factors: local bone quality, available space (in particular for interradicular insertion) and mucosal thickness. Furthermore, the expected load on the mini-implant should be taken into consideration.

5.1.1 Direct anchorage

In a direct anchorage situation, the implant is directly connected to the dental unit(s) to be moved. In this manner, a purely mini-implant supported anchorage is the result. Depending on the treatment objective, forces can be transferred from the implant to the dental unit(s) using the following modules.

Compression Spring (Fig. 5-1)

The use of a compression spring always requires an additional arch wire or wire segment to stabilize the compression spring (open coil spring). The insertion can sometimes be difficult, and regular reactivation or a change to a new, longer spring is often required. This can often be done without removing the entire set-up by crimping a stop or using an arch lock on the arch wire or segment. It is for these reasons that tension mechanics are often preferred.

Tension Spring (Fig. 5-2)

Super-elastic nickel titanium (NiTi) springs (closed coil springs) are biomechanically more favorable than elastic chains due to their consistent and constant force delivery. Depending on the make of the tension spring and head design of the mini-implant, it may be necessary to attach the spring using a stainless steel ligature or Monkey Hook (American Orthodontics, Sheboygan, WI). Some



Fig. 5-1 Direct anchorage with compression spring: a compression spring is applied on a 16 x 22 NiTi segmented arch between mini-implant (interradicular between teeth 6 and 5) and tooth 3. This allows for distalization and de-rotation of the latter.



Fig. 5-2 Direct anchorage with tension spring: the NiTi-tension spring facilitates the mesialization of tooth 19. The power hook reduces friction.



Fig. 5-3 Direct anchorage with elastic chain: en masse retraction of maxillary anterior teeth following extraction of the first premolar.

mini-implant systems now offer custom-made auxiliaries, available in specific auxiliary kits, to fit a specific mini-screw perfectly (e.g. tomas® Auxiliary Kit, Dentaaurum).

Elastic Chain (Fig. 5-3)

As a rule, tension mechanics with an elastic chain can be applied quickly and without complications. A disadvantage with the chain, in contrast to a NiTi tension spring, is the rapid force decay of the elastic materials. Since a NiTi tension spring is not applicable for short distances of tooth movement, the elastic chain is better suited.



Fig. 5-4 Direct anchorage with lever arm: mesialization of teeth in left maxillary quadrant through lever mechanics.

Lever Arm (Fig. 5-4)

In certain cases, the insertion of a mini-implant in a desired location is not possible (mostly for anatomical reasons such as insufficient quality bone or lack of interradicular space). By using lever-arm mechanics, these problems can often be resolved. Since mini-implants should not be subjected to significant torque loads, especially in the unscrewing direction, it may be necessary to insert two mini-implants for support. In these instances, mini-implants with cross-slot or bracket heads are required for the attachment of orthodontic wires. Then a segment of rectangular wire (titanium molybdenum alloy [TMA] or stainless steel [SS]) is bent so that it can be inserted into the slots of both mini-implants and fixed in place using light-cured adhesive (e.g. TransBond, Fa. 3M Unitek). The adhesive also acts to "round-the-edges" of the mini-implant/wire to reduce the likelihood of mucosal irritation. If large mechanical loads are to be expected, a wire ligature can first be placed before the adhesive is applied.

Wire Ligature, Tube and Compression Spring (Fig. 5-5)

If typical tension mechanics are limited due to anatomic conditions, then the combination of tube and compression spring can be employed. To ensure direct anchorage to the mini-screw, the tube must be freely movable on the arch wire. If indirect anchorage is desired, then the tube will be compressed or crushed to affix it solidly on the arch wire.

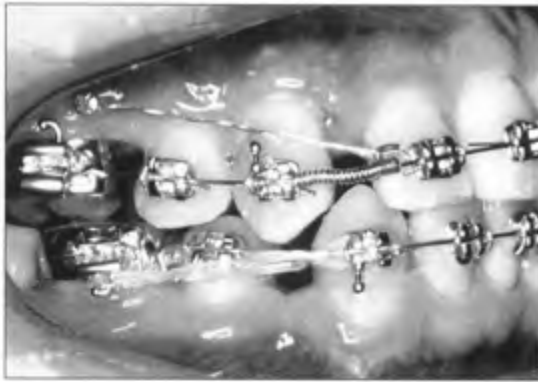


Fig. 5-5 Direct anchorage with ligature, sliding jig and compression spring: the compression spring is put under pressure by the sliding jig and wire ligature and thus distalizes tooth 6. If the tube is freely movable on the arch and is not restricted by brackets, direct anchorage results. To include the anterior dentition into the anchorage segment, the jig is crimped on the arch and indirect anchorage results.



Fig. 5-6 Indirect anchorage with segmented arches and cross tubes: the mini-implant stabilizes the premolars via 17 x 25 stainless steel segmented arch and cross tube to achieve mesialization of tooth 15.

Advantages of Direct Anchorage

- Simple activation
- Efficient mechanics
- Easy to delegate
- No dental anchorage loss (movement or loss of the mini-screw is possible if applied forces are too substantial)

Disadvantages of Direct Anchorage

- Greater load is applied directly to the implant than with indirect anchorage (with indirect anchorage, the load is distributed over both the mini-screw and dental anchorage unit)
- Poor force control in three dimensions
- Mechanics are not fail safe (treatment progress should be monitored closely)

5.1.2 Indirect Anchorage

When indirect anchorage is employed, the mini-screw stabilizes the dental anchorage unit and an implant-reinforced dental anchorage segment is the result. Depending on the individual requirements, the following are methods for constructing indirect anchorage biomechanics:

Segmented Arches and Cross Tubes (Fig. 5-6)

A dental anchorage unit can be reinforced using a segmental wire, extending from a mini-screw, inserted into a cross tube on the base arch wire. Typically, the mini-implant should be

placed opposite to the direction that the dental anchorage unit would move. For example, if anchorage of maxillary anterior teeth is desired in the vertical dimension, then the mini-implant should be inserted in the buccal bone. If, however, lingual tipping of the maxillary anterior teeth must be avoided, palatal placement of the implant is recommended.

To avoid anchorage loss due to deformation of the segmental arch wire, a minimum of 17x25 stainless steel should be employed, and ideally the segment should be as short as possible. Therefore, it is recommended that mini-implants be inserted as close as possible to the cross tube. Furthermore, any sliding of the wire segment through the cross tubes or slots of the mini-screw should be avoided. This can be realized by a step bend, or by roughening the surface of the wire segment and by fixing it in place with composite. Although this type of anchorage is very useful, it can occasionally be difficult to construct and apply in some clinical situations.

Segmental Arch and Bands with Auxiliary Slot (Fig. 5-7)

Another alternative uses segmental wires that are attached to the mini-screw and then bent to fit into the horizontal auxiliary slot on a molar band. This set-up is quite convenient for molar anchorage and can be installed relatively easily.



Fig. 5-7 Indirect anchorage with segmented arch in the auxiliary slot: the mini-implant prevents mesialization of tooth 3 while retracting tooth 6.



Fig. 5-8 Indirect anchorage with segmented arch and composite on acid etched enamel: the mini-implant stabilizes tooth 11 by bonding the wire directly to the tooth. Tooth 14 will be mesialized to replace missing tooth 13.

Segmental Arch and Acid Etch Technique (Fig. 5-8)

The easiest way to create absolute anchorage support for anterior teeth involves direct bonding (acid etch technique) of a segmental wire to the surfaces of one or two teeth (molars or premolars). In this manner, the segmental wire is short and helps to prevent loss of anchorage by deflection of the wire.

Connection with Transpalatal Arch

(TPA) / Quadhelix (QH) / Horseshoe Arch
A Quadhelix or a Transpalatal Arch can be stabilized using a palatally inserted mini-implant. For mini-implants that feature a very wide slot, it is possible to directly integrate the TPA/QH (Fig. 5-9). As most of the mini-implants have a



Fig. 5-9 Indirect anchorage using transpalatal arch: the mini-implant with wide slot inserted into the median palatal suture prevents tipping of the molars via the transpalatal arch. The treatment objective was the extrusion of the retained tooth 11 using a segmented arch in the vestibule.

smaller slot (.022), the following technique is recommended. A matrix of wire ligature or passive elastic chain is stabilized using a highly filled composite (Fig. 5-10). The distance between the mini-implant and wire should be kept short and the wire surface should be roughened or etched to create better retention with the composite.

When anchorage to resist mesial molar migration is required, mini-implants should generally be placed more anteriorly. Then the connection from a Horseshoe Arch or a Quadhelix can be made to the mini-implant (Fig. 5-10). Inserting the mini-implant in the middle of the posterior hard palate typically provides sufficient anchorage for the molars (see Fig. 5-9).

Wire Ligature (Fig. 5-11)

Using a wire ligature is certainly the easiest way to secure the mini-screw to the dentition.

Wire Ligature, Tube and Compression Spring (see Fig. 5-5)

Indirect anchorage is produced when the tube is compressed or crimped onto the arch wire. Traditional orthodontic mechanics can then be used to transfer forces from this implant-supported dental anchorage unit to the teeth that are intended to be moved.



Fig. 5-10 Indirect anchorage using a quadhelix: the quadhelix with roughened surface is coupled to the mini-implant with light cure composite (with a wire ligature or elastic chain providing the matrix). The treatment objective is anchoring the molars while retracting tooth 5.



Fig. 5-11 Indirect anchorage using a wire ligature: the mini-implant in the area of the tuberosity is preventing mesialization of tooth 15 during the retraction of the premolars.

Advantages of Indirect Anchorage

- Generally less load is applied to the implant than with direct anchorage
- Simple, conventional mechanics
- Easy to delegate
- Fail-safe mechanics

Disadvantages of Indirect Anchorage

- Loss of anchorage in terms of undesired dental movement of the anchorage teeth is possible
- Classic example: mesial migration of the premolars when distalizing molars using a dentally supported pendulum device
- More complicated and time consuming to install
- Breakage of appliance may go unnoticed and result in anchorage loss

5.2 Clinical Solutions for Different Indications

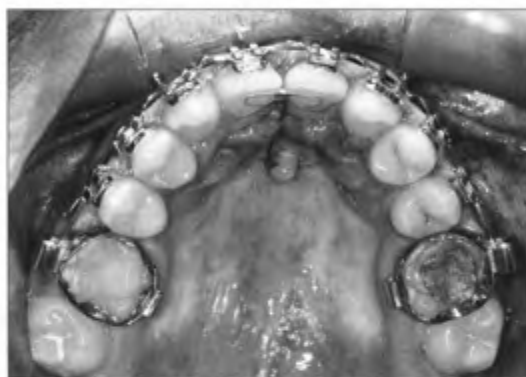
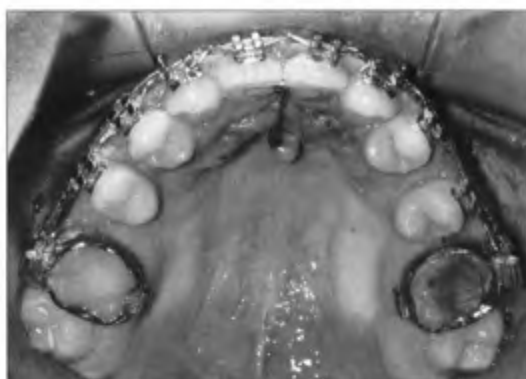
In the following sections, anchorage strategies using mini-implants are described for specific clinical applications. As always in orthodontics, there is often more than one possible solution to most clinical problems – this also applies to the use of mini-implants. Therefore, the following overview of possible applications is by no means complete; we simply could not demonstrate all of the possible clinical problems and anchorage solutions with mini-implants. The purpose was to compile some sort of “cookbook” in which the clinician may find treatment suggestions for particular indications

and then modify them to an individual patient’s needs.

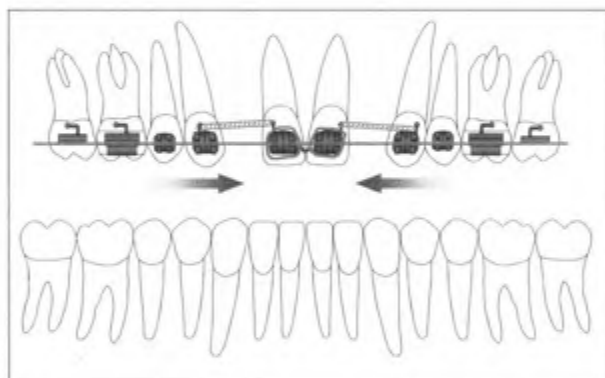
Whatever clinical situation the orthodontist may be confronted with, he/she should never forget the basic and traditional treatment approaches learned in residency. Many case reports for mini-implants found in the current literature often feature patients that may have been treated just as well using traditional or “old fashioned” mechanics. Another critical development may be the risk of no longer offering any mechanics that require patient compliance, a situation that could lead to over-treatment. Common sense, caution, and specific and individual treatment planning are critical. This advice also applies to evaluating the examples discussed in this chapter. Many of the indications listed below could also be achieved using only traditional mechanics. Remember that not all cases are the same, even if they present with similar dental problems. Communicating with patients as part of consultation and informed consent are crucial when planning and presenting treatment options. This topic will be explored in greater detail in a later chapter.

On the Use of this Guide

As previously mentioned, in most cases there are two possible anchorage solutions with mini-implants: indirect and direct. This must be taken into consideration when using this guide. Subsections reference the tooth or groups of teeth that are directly connected to the implant. As an example, combining ante-



Sketch 5-1, Case 1 The buccal segments are protracted in a case of agenesis of the maxillary lateral incisors. A mini-implant is inserted palatally and connected to the maxillary central incisors by a 17 x 25 ss wire segment to maintain the overjet. This wire segment is attached to the central incisors using light cure composite.



rior teeth and mini-implant as an indirect anchorage unit can support protraction of molars (section 5.2.1.1, "Anchorage of Anterior Teeth"). Should, however, direct anchorage be chosen (forces of protraction are directly applied to the mini-implant), this option can be found in section 5.2.3.4, "Mesialization of Posterior Teeth". The same situation applies to section 5.2.1.3, "Retraction of Anterior Teeth" and section 5.2.3.1, "Anchorage of Posterior Teeth".

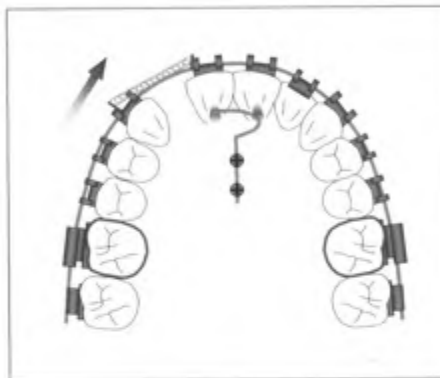
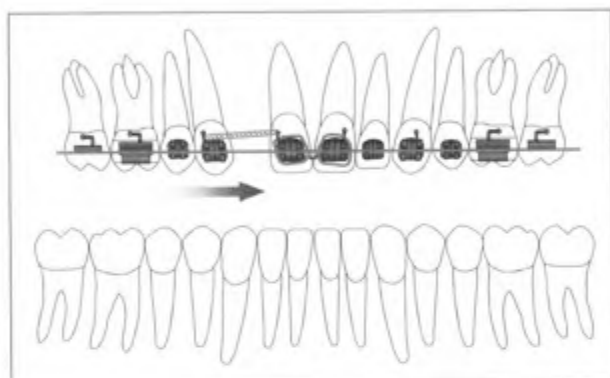
5.2.1 Anterior Teeth

5.2.1.1 Anchorage of Anterior Teeth

Maxilla – Horizontal Plane

If the maxillary anterior segment is to be stabilized in a horizontal direction against lingual

tipping and to maintain overjet, then a mini-implant should be inserted in the palate. If the goal is bilateral protraction, as for example in agenesis of the upper lateral incisors, the insertion of one single mini-implant is usually sufficient (Sketch 5-1, Case 1). Should the space closure be carried out asymmetrically, which means that an asymmetric, unilateral load is applied to the dental anchorage unit, the insertion of two mini-implants becomes necessary to counteract any moment that may result at the implant (Sketch 5-2, Case 2). To avoid a loss of anchorage, light counter-activation of the segmental arch (fixed in this position by light-cured composite) can be helpful. When inserting a mini-implant in this area, one should consider that the incisive foramen is directly in the area of the incisive papilla.



Sketch 5-2, Case 2 In agenesis of tooth 7, unilateral space closure is attempted. Two mini-implants serve as anchorage, and are connected with the central incisors with a 17 x 25 ss wire segment and light-cured composite.

Maxilla - Vertical Dimension

To achieve stabilization in the vertical dimension (i.e. to maintain overbite) the insertion of a mini-implant in the buccal cortical bone is recommended. The connection to the dental anchorage unit can be achieved either by using a segmental arch with cross tube (Sketch 5-3, case 3) or with a composite connection. For active anterior extrusion, the segmental arch can be used in combination with a compression spring (Fig. 5-12, see section 5.2.1.2).



Fig. 5-12 A compression spring on the wire segment can create extrusion.

Mandible – Horizontal Plane

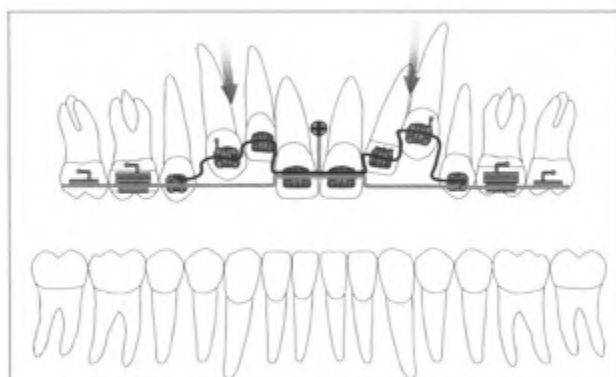
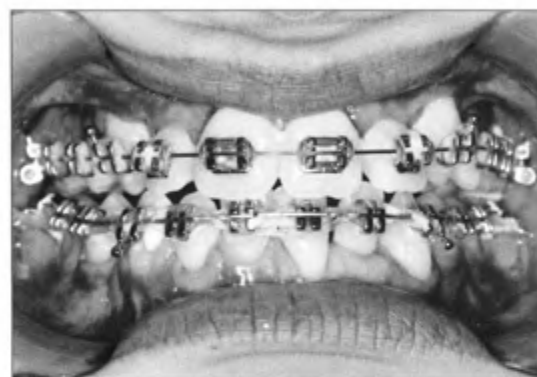
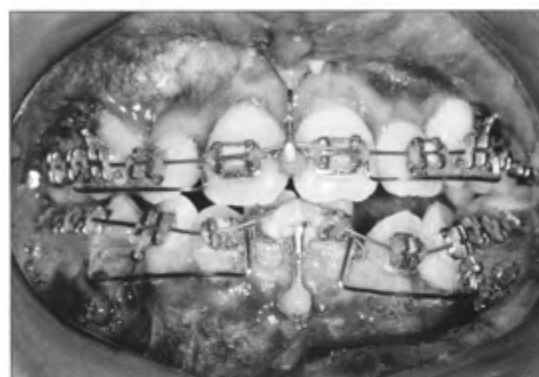
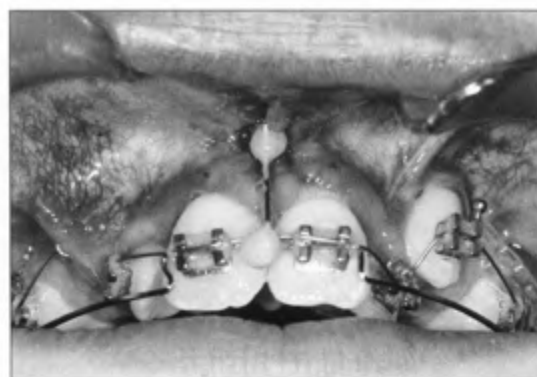
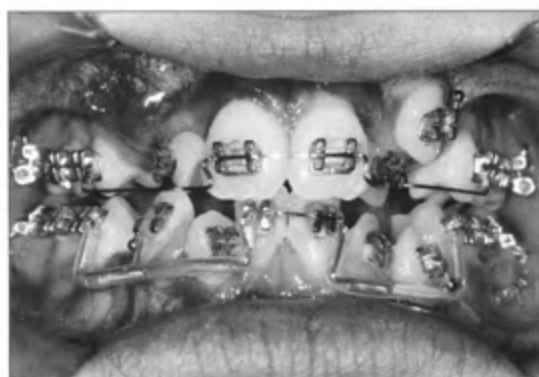
The mandibular anterior segment can be stabilized in the horizontal plane by a mini-implant placed in the area of the posterior alveolar process. Limiting the protrusion or flaring of the mandibular anterior teeth is important when a fixed functional appliance like the *Herbst*, *Jasper Jumper*, or even when Class II intermaxillary elastics are employed. In these instances, the mandibular dentition can be ligated or “tied-back” to the mini-implant (Sketch 5-4, Case 4). If resistance to any anterior retraction is desired, then a stable segmental arch is required (Sketch 5-5, Case 5).

Mandible – Vertical Dimension

Anchorage in the vertical dimension for the mandible can be created analogously to the examples shown for the maxilla (see Case 3).

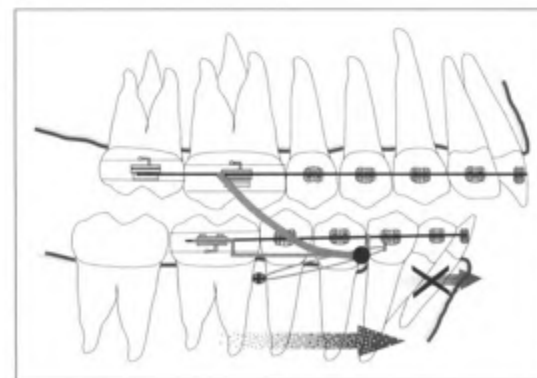
5.2.1.2 Intrusion/Extrusion of Anterior Teeth

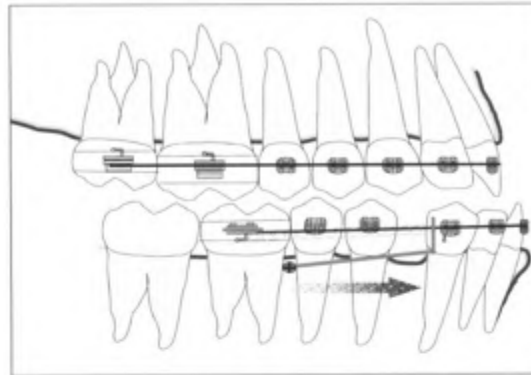
Should direct symmetrical intrusion be chosen, at least two mini-implants are necessary (Sketch 5-6, Case 6). If the incisors are retroclined (e.g. Class II Division 2), the use of a tension spring or



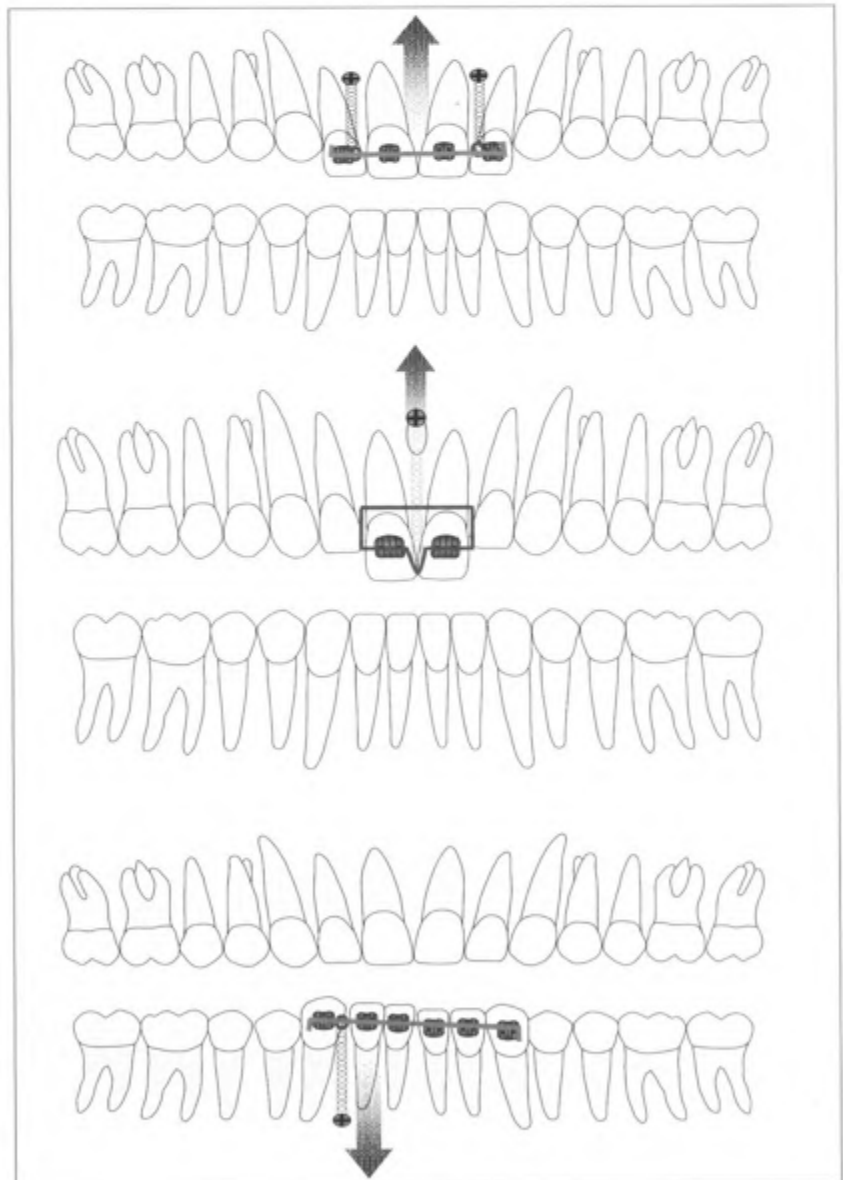
Sketch 5-3, Case 3 The retained maxillary and mandibular teeth are extruded. As a consequence, a reciprocal intrusive force acts on the central incisors. Mini-implants and segmented arch wires with cross tubes stabilize the overbite.

Sketch 5-4, Case 4 Bilateral mini-implants in the mandible anchor the anterior teeth against protrusion during class II correction with the *Herbst* appliance.

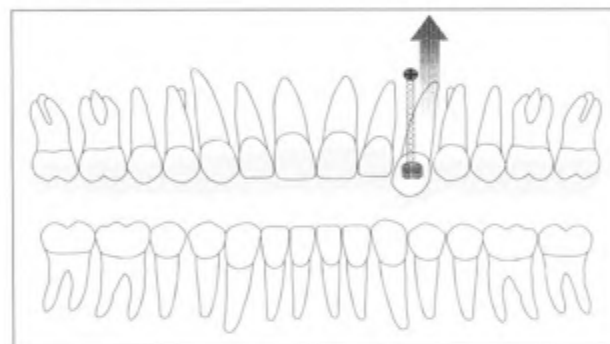




Sketch 5-5, Case 5 For pre-surgical decompensation, the mandibular buccal segments are protracted. The mini-implant provides direct anchorage, as the tube is able to slide. A disadvantage is that after premolar protraction the mini-implant will have to be removed and replaced in a different position to protract the molars (photo by Dr. B. Böhm, Halle).



Sketch 5-6, Case 6 For symmetrical intrusion, at least two mini-implants are used. If the anterior teeth are severely protruded, the springs can be diverted by a rectangular segmental arch wire. If an asymmetrical intrusion is desired, one mini-implant may be sufficient (photo by Dr. B. Ludwig, Traben-Trarbach).



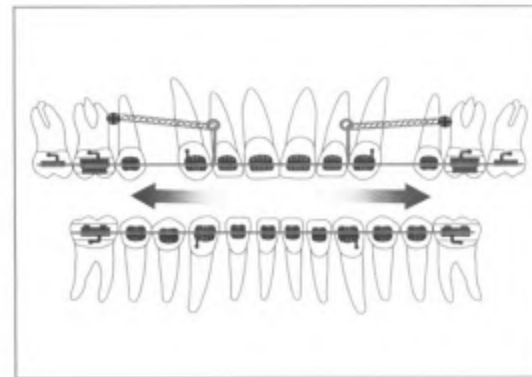
Sketch 5-7, Case 7 The left cuspid is intruded using mini-implant anchorage. The thermoplastic splint prevents undesired tooth movements while allowing for intrusion (photos Dr. C. M. Ludwig, Dr. J. Seiferth, Mainz).

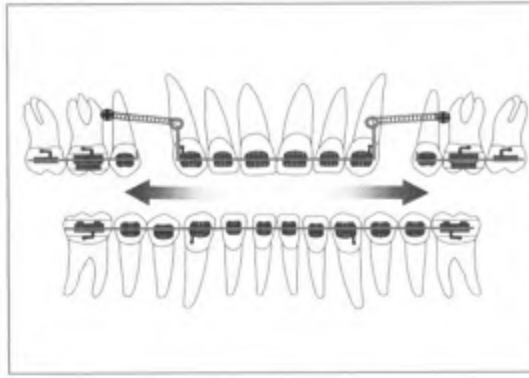
an elastic chain may result in irritation or impingement of the gingiva. In that situation, the diversion of the tension spring by means of a rectangular segmental arch is recommended. Since there is little space between the roots of the mandibular incisors, the insertion of the

mini-implants should be in the area of the root apices or slightly lower (more apical); often requiring a "stab" incision or tissue punch through the buccal mucosa before implant insertion. If an asymmetrical intrusion is desired, one single implant may be sufficient. Due to the buccal

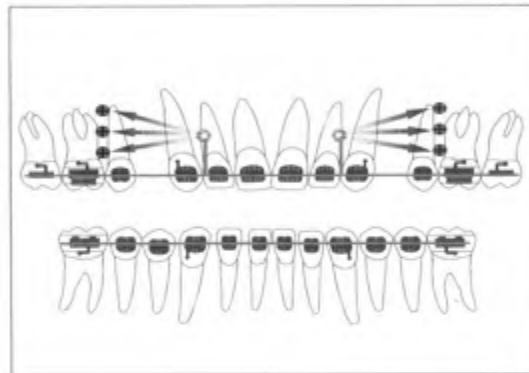


Sketch 5-8, Case 8 After extraction of the maxillary first premolars, the anterior teeth are retracted using sliding mechanics. Mini-implants mesial to the first molars are used for anchorage.

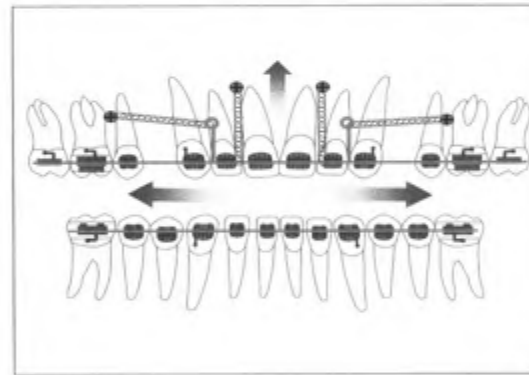




Sketch 5-9, Case 9 Same patient as in Case 8. To avoid the undesired side effects of friction, retraction mechanics were changed to segmental retraction. When comparing this situation with Case 8, the undesired distalization of the second premolars due to friction can be observed (see also Sketch 5-43).



Sketch 5-10 Different force vectors depending on the insertion site of the mini-implant during anterior retraction.



Sketch 5-11, Case 11 Combination of two posterior mini-implants for anterior retraction and two anterior mini-implants for intrusion (photo by Prof. H. M. Kyung, Korea).

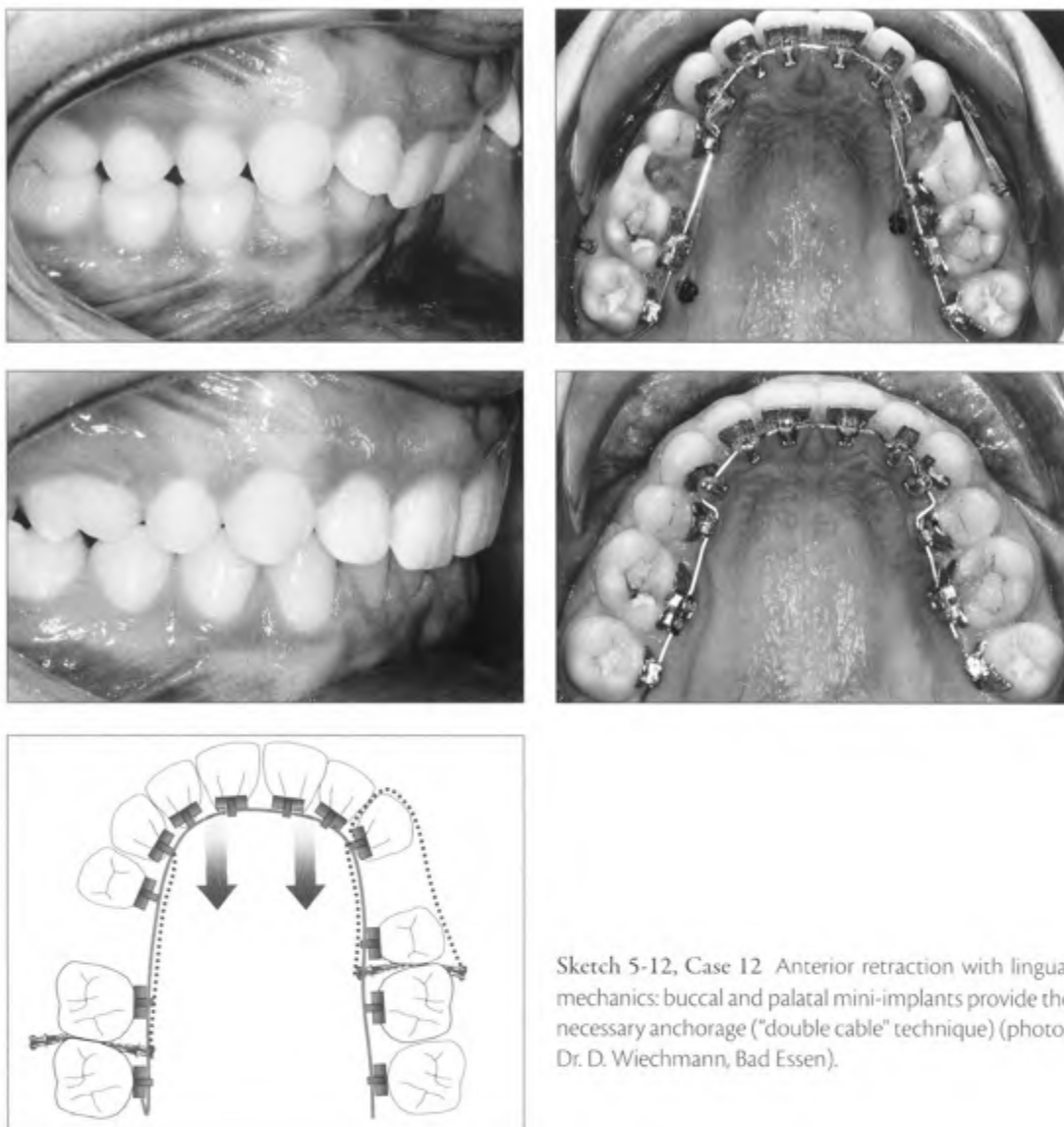
point of force application, teeth may have a tendency to tip buccally. This can be limited by using a thermoplastic splint (Sketch 5-7, Case 7).

5.2.1.3 Retraction of Anterior Teeth

One of the classic indications for mini-implant anchorage is the retraction of the maxillary anterior segment. Sliding mechanics (using small hooks firmly crimped to the arch wire; Sketch 5-8, Case 8) can be subject to high frictional loads as the arch wire translates through the bracket slots, especially when second molar bonds or bands are in place. To compensate

for these frictional loads, higher forces must then be applied to the mini-implant. These forces can be reduced if anterior retraction is carried out in segments (Sketch 5-9, Case 9).

The further apically that mini-implants are placed, the greater the bite opening when direct anchorage is employed, due to the different resulting force vectors (Sketch 5-10). In deep-bite cases, mini-implants should be placed as apically as possible whether in the maxilla or mandible. However, due to anatomic restrictions (e.g. buccal mucosa, lack of bone) this may not always be possible. Here, one or two additional mini-implants, placed in the area of the central inci-



Sketch 5-12, Case 12 Anterior retraction with lingual mechanics: buccal and palatal mini-implants provide the necessary anchorage ("double cable" technique) (photos Dr. D. Wiechmann, Bad Essen).

sors, can be used for bite opening as described above. This will result in some anterior retraction along with intrusion (Sketch 5-11, Case 11).

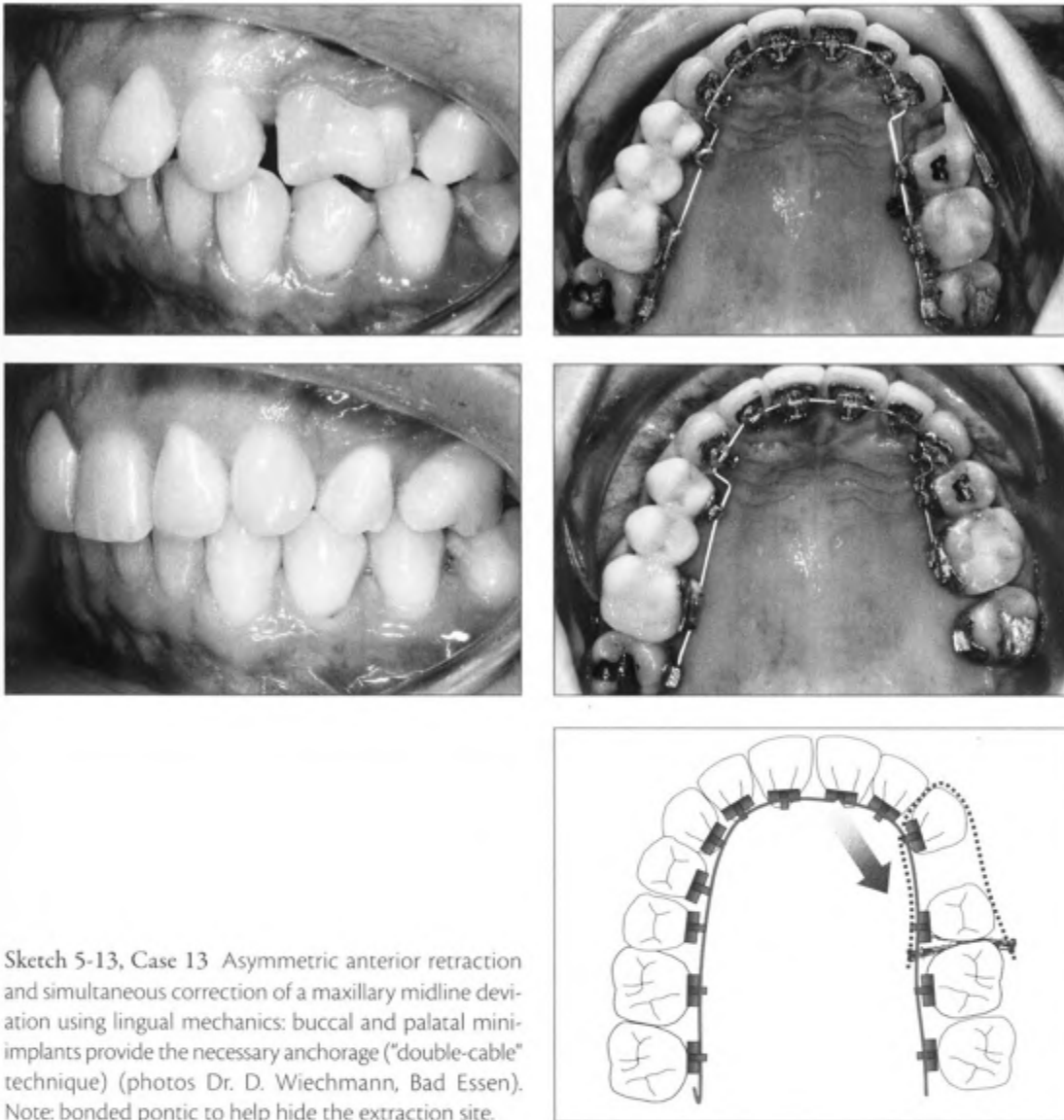
If lingual orthodontics are used, then a mini-implant that is inserted in the palate makes sense (Sketch 5-12, Case 12; Sketch 5-13, Case 13). Mini-implants may also be inserted in the median palate. Here the advantages of abundant bone supply are combined with those of insertion in attached gingiva, without the risk of root injury (Sketch 5-14).

5.2.2 Canines

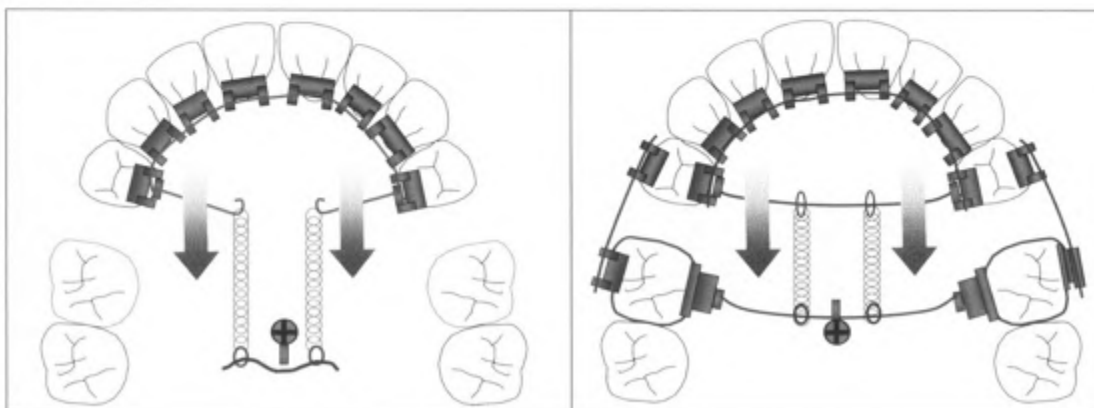
5.2.2.1 Canine Retraction

When premolars are extracted to assist in resolving severe crowding or protrusion, the canines must be retracted first, prior to retraction of the

other incisors. If a canine is tipped mesially, an elastic module can be directly inserted between mini-implant and bracket, and then retraction can be initiated without an arch wire (Sketch 5-15, Case 15). If, however, distal tipping is not desired, then controlled canine retraction (along an arch wire; Sketch 5-16), or by incorporating a power arm (Sketch 5-17, Case 17) are recommended. Often, however, the ligation of a power arm to a bracket is difficult unless there is a vertical slot. Furthermore, depending on the length of the segmental arch or hook, and the height of the vestibule, this can often result in mucosal ulcerations. Using a continuous step arch to avoid the anterior teeth (Sketch 5-18), "flaring" of the buccal tooth segments that is often observed during canine retraction using conventional mechanics, may be avoided. Afterwards, the same mini-implants used for canine retrac-

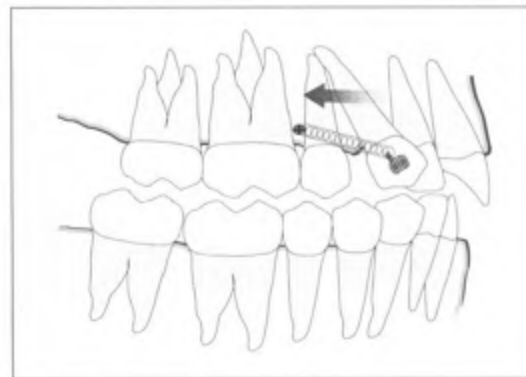


Sketch 5-13, Case 13 Asymmetric anterior retraction and simultaneous correction of a maxillary midline deviation using lingual mechanics: buccal and palatal mini-implants provide the necessary anchorage ("double-cable" technique) (photos Dr. D. Wiechmann, Bad Essen). Note: bonded pontic to help hide the extraction site.

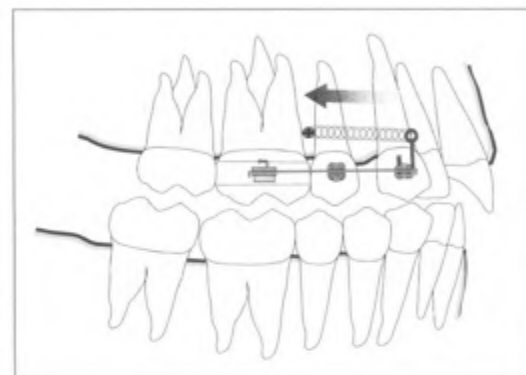


Sketch 5-14 Different options for anterior retraction with only one palatal implant. Here the advantages of sufficient bone and attached gingiva are combined, while root damage is impossible.

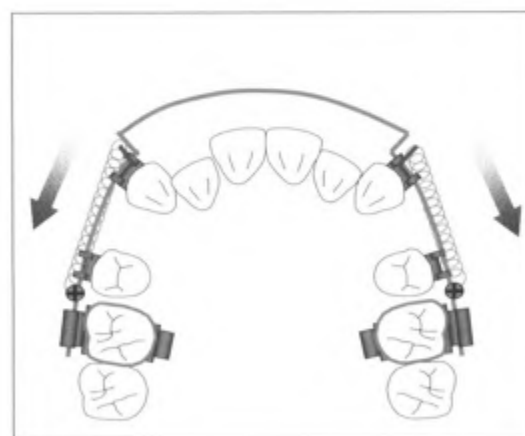
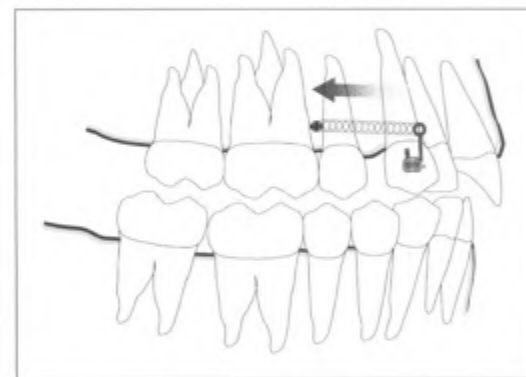
Sketch 5-15, Case 15 Retraction of right canine with an elastic chain connected to the mini-implant.



Sketch 5-16 Segmental sliding retraction of right canine with power-hook and retraction spring connected to the mini-implant.



Sketch 5-17, Case 17 Retraction of right canine with power-hook and elastic retraction spring.

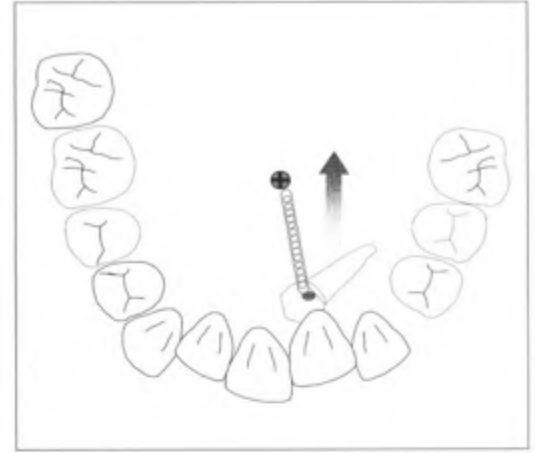


Sketch 5-18, Case 18 Retraction using a continuous stepped arch wire, bypassing the anterior teeth, to prevent flaring of the buccal segments.

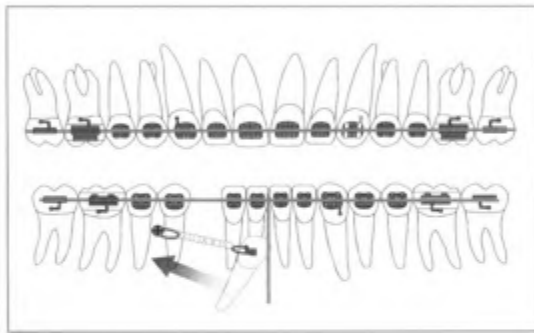
tion can then be used as direct anchorage for subsequent retraction of the entire anterior segment, once leveling is complete (see section 5.2.1).

5.2.2.2 Integration of Displaced Canines

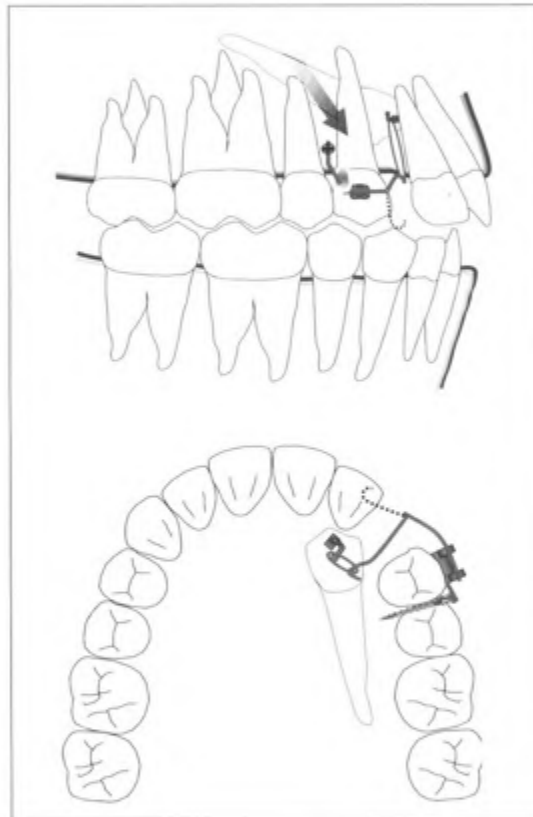
Mini-implants can also be a valuable support for the integration of displaced canines. Depending on the direction of displacement of the canines, an individual plan must be made. If, for example, a posteriorly directed force is required in the maxilla, the mini-implant should be inserted in the area of the palatal suture (Sketch 5-19, Case 19). An insertion in the alveolar process may also make sense if maximum anchorage for the integration of canines is required (Sketch 5-20; Sketch 5-21).



Sketch 5-19, Case 19 Distalization of apically displaced left canine using a mini-implant in the posterior midpalatal suture.



Sketch 5-20 Retraction of right canine with mini-implant anchorage.

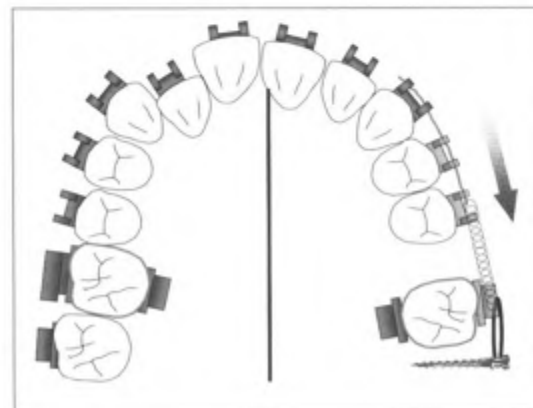


Sketch 5-21 Alignment of displaced left canine with a TMA spring. Anchorage is provided by the mini-implant connected with a bonded wire segment to the first premolar.

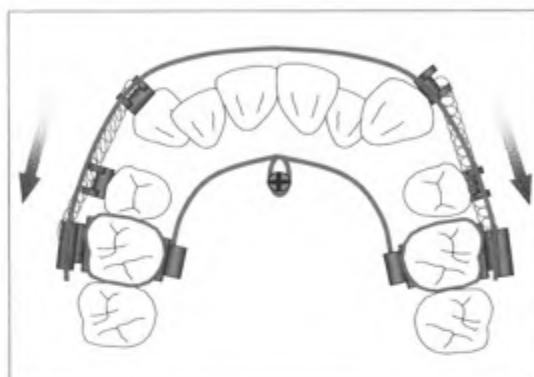
5.2.3 Posterior Teeth

5.2.3.1 Anchorage of Posterior Teeth

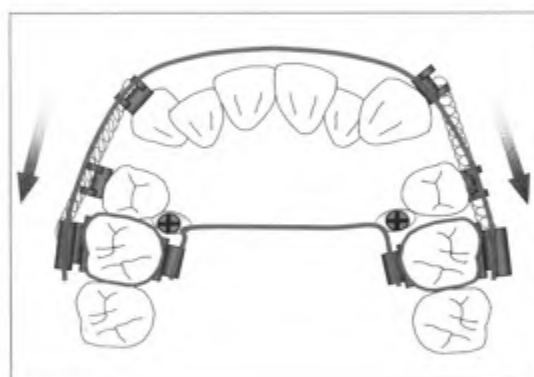
A quick method to stabilize molars against mesial migration involves placing a mini-implant behind the molar and then tying it to the molar. This can be an option when retraction of premolars and/or anterior teeth is planned (Sketch 5-22, Fig. 5-11). In this respect, however, the reduced bone quality and relatively thick gingiva distal to the maxillary molars are a disadvantage. As a consequence, a rather high risk of implant loosening or premature loss exists. The result could be undesired anchorage loss and might be prevented by connecting two mini-implants, pitted against the direction of force application (see section 5.2.3.5, posteri-



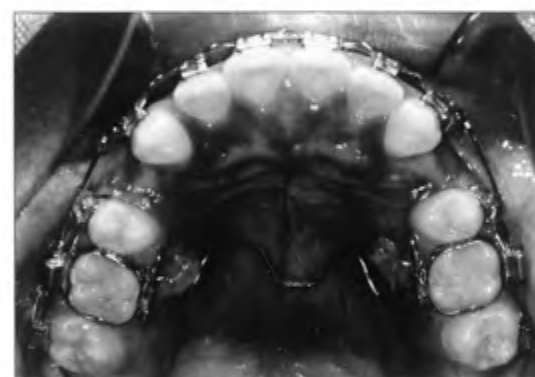
Sketch 5-22 The mini-implant provides anchorage for left second molar while distalizing the left buccal segment and correcting the midline deviation.



Sketch 5-23, Case 23 Anchorage of first molars using a horseshoe arch and an anterior midpalatal implant.



Sketch 5-24 Indirect anchorage using a transpalatal arch and mini-implants close to the center of resistance of the molars.

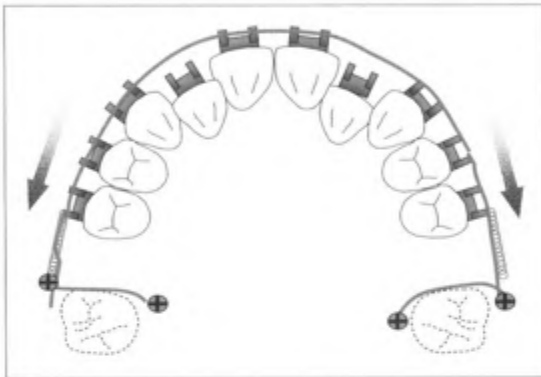


or teeth, distalization). Furthermore, there is also the possibility of anchoring the molars with a Horseshoe Arch or Quadhelix to a mini-implant in the anterior median palate (Fig. 5-10, Sketch 5-23, Case 23). There is good bone support for the mini-implant as well as a thin and tight gingiva in that region. Another advantage is that there is no danger of root damage, in contrast to insertion of the mini-implant in the alveolar process.

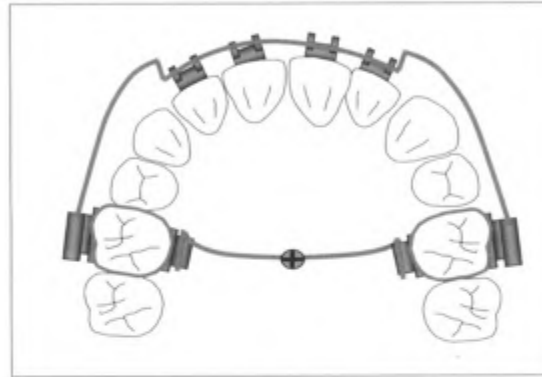
Another possibility for horizontal anchorage exists using a transpalatal arch (TPA). When using a TPA, the mini-implants should not be inserted into the median palate, but close to the center of resistance of the molars (Sketch

5-2, Case 24). If teeth to be anchored are not yet completely erupted (banding not yet possible), segmental arches between two implants can prevent undesirable tooth migration (Sketch 5-25, Case 25). At this point, it should be mentioned that the failure rate of mini-implants is much greater in recent extraction sites for about 6 months.

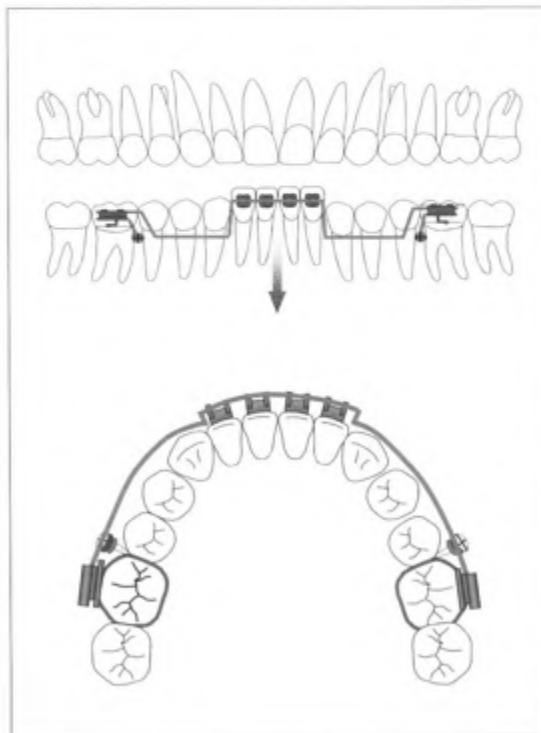
Anchorage of molars may also be necessary in directions other than the horizontal plane. When extruding or intruding anterior teeth with a Ricketts' utility arch, undesirable moments are applied to the anchoring molars. Mini-implants can be used to avoid this reactive molar tipping. Apart from using a Quadhelix or Horseshoe



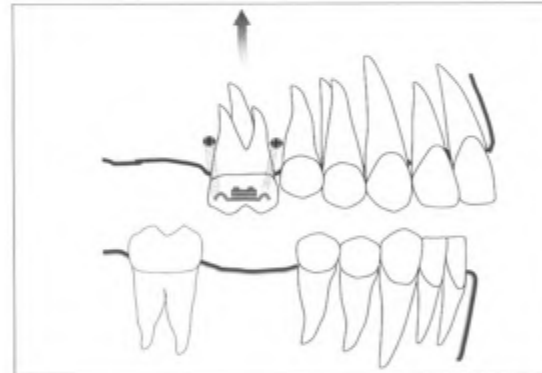
Sketch 5-25, Case 25 Anchorage alternative to incompletely erupted second molars (banding not possible) with arch wire segments between two implants.



Sketch 5-26 The mini-implant anchored transpalatal arch prevents tipping of the molars when using a utility arch.



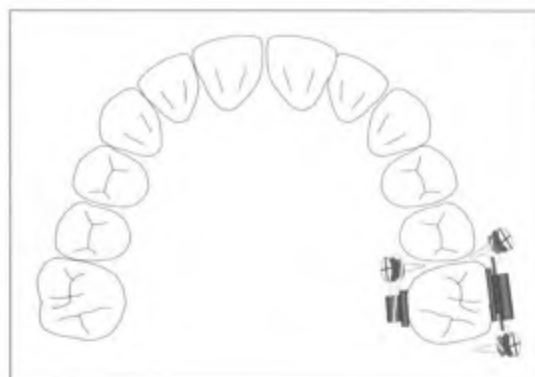
Sketch 5-27 Molar anchorage provided by mini-implants that are coupled with the molars by arch wire segments inserted into the auxiliary slot of the molar bands. Undesired tooth movement (i.e. molar tipping) is prevented during the use of a utility arch.



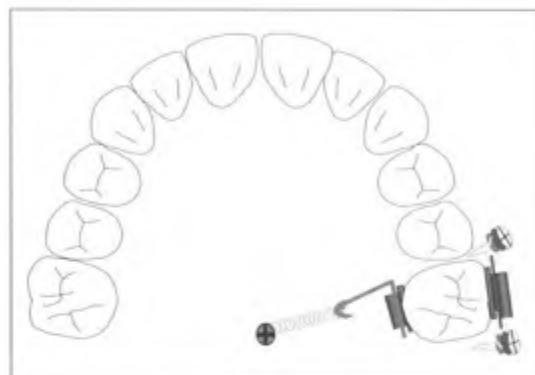
Sketch 5-28 Two buccal mini-implants for molar intrusion (distal and mesial to the molar).

Arch for anchorage, a TPA attached to a mini-implant in the median palate can also be used (Sketch 5-26, Fig. 5-8). Molar anchorage is also possible using segmental arches connected to the mini-implants using the double (auxiliary) tubes on either upper or lower molar bands (Sketch 5-27).

Sketch 5-29, Case 29 To prevent tipping of the molars during intrusion, force is applied buccally and mesially (here in the area of the alveolar process) (photo by Dr. B. Glasl, Frankfurt).



Sketch 5-30, Case 30 To prevent tipping of the molars during intrusion, force is applied buccally and mesially (here in the area of the median palatal suture).



5.2.3.2 Intrusion of Posterior Teeth

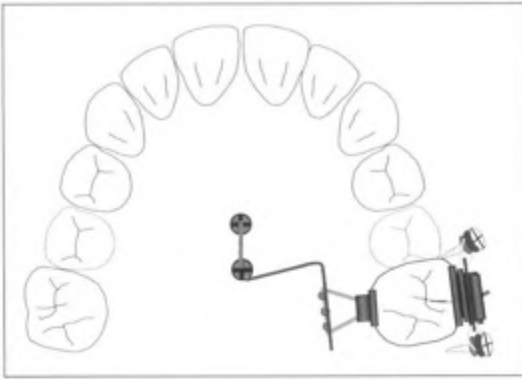
The intrusion of molars is a task that can be achieved only with great difficulty without skeletal anchorage (e.g. occipital headgear, Multiloop-Edgewise-Archwire [MEAW] arches). Besides closure of an open bite, pre-prosthetic intrusion of hyper-erupted molars is another of the classic indications for mini-implant anchorage. To prevent buccal flaring of molars during their intrusion, force application is necessary on both the buccal and the palatal sides of the tooth. Typical mechanics consist of two mini-implants placed in the buccal alveolus (i.e. distal and mesial of the tooth to be intruded, Sketch 5-28) and one mini-implant in the palate. In this procedure, the palatal implant can be inserted either in the alveolar process (Sketch 5-29, Case 29) or in the median palatal suture (Sketch 5-30, Case 30). Insertion of the mini-implant in the palatal alveolus carries some risk of root injury and/or the molar intrusion could be impeded by contact with the mini-implant. In most instances, insertion into the median palate seems to be advantageous when force application from the palate is desired.

The amount of available bone and the clinical evaluation of the transition from soft to hard palate are important. If insertion of a mini-

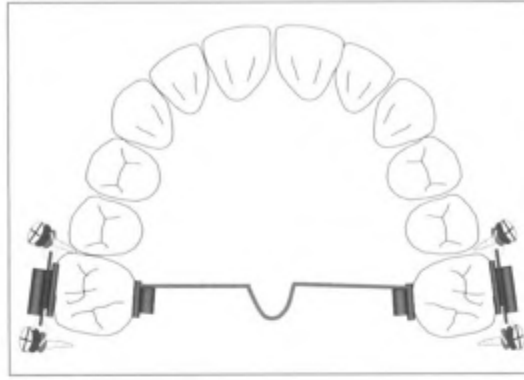
screw is not possible mesial to the molar that is to be intruded, then two mini-screws may be inserted more anteriorly. Then the line of action can be directed posteriorly by means of a lever arm (Sketch 5-31). These lever arm mechanics are also useful for patients that have a severe gag reflex.

If two contra-lateral molars are to be intruded in the maxilla, then a transpalatal arch is sufficient to prevent buccal tipping (Sketch 5-32). To avoid interference with the palatal mucosa, 5 mm of clearance should be built in to the construction of the TPA to allow for the intrusion. Depending on the interradicular distance, lever mechanics are again an alternative (Sketches 5-33, 5-34, 5-35, Case 35). For intrusion of premolars and anterior teeth, similar options exist (Sketch 5-36, see section 5.2.1.2).

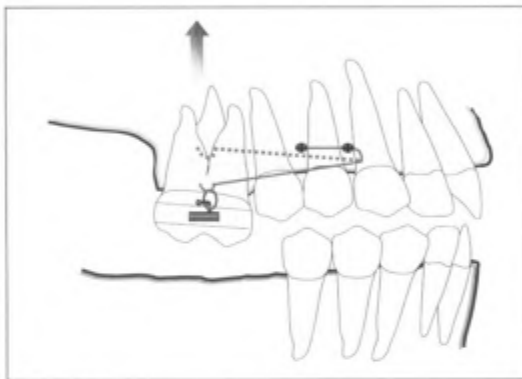
Intrusion of mandibular molars is also possible; however, insertion of mini-screws in the lingual alveolus is not recommended due to the high rate of loss. A lingual arch is used to avoid buccal tipping when mini-screws are inserted into the buccal alveolus.



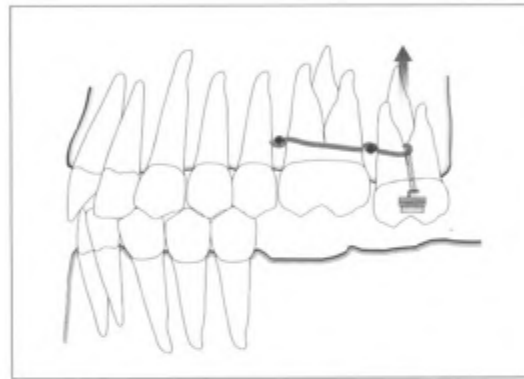
Sketch 5-31 Two mini-implants in the anterior portion of the median palatal suture with lever arm to prevent tipping of the molar during intrusion.



Sketch 5-32 Use of a transpalatal arch to prevent tipping of the molars during intrusion of contralateral teeth.



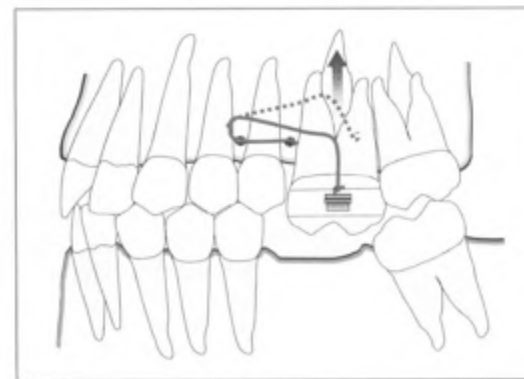
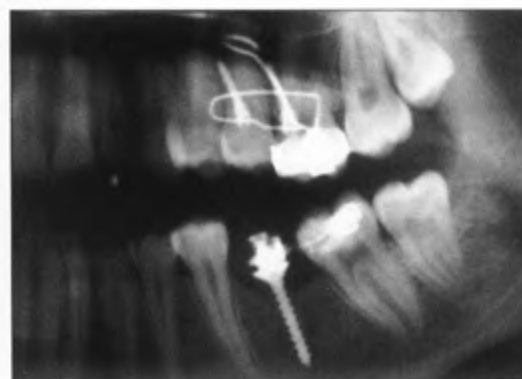
Sketch 5-33 Due to lack of space mesially or distally to the molars, buccal lever mechanics with a TMA wire are used for molar intrusion.

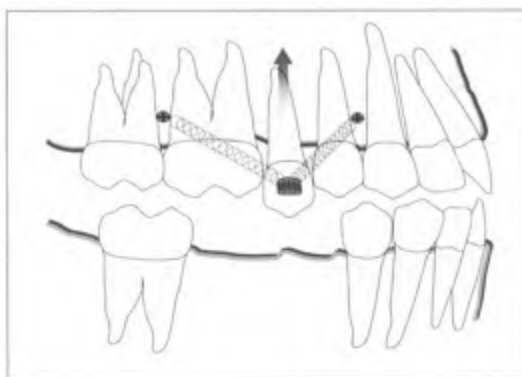


Sketch 5-34 Molar intrusion with buccal lever mechanics using stainless steel wire and elastic module.

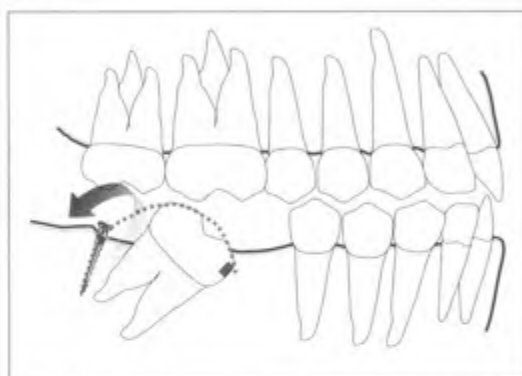


Sketch 5-35, Case 35 Intrusion of left first molar: lack of space distally (Panorex at the beginning of treatment) necessitates buccal lever mechanics with a TMA arch wire. Uprighting of left second molar in the mandible using a compression spring and a 16 x 22 NiTi arch wire that is ligated into a bracket/band on the mini-implant (see also Sketch 5-37). (Wilmes, B, Drescher, D. Verankerung mit Miniimplantaten bei präprothetischer kieferorthopädischer Therapie. *Kieferorthopädie* 2006; 20(3):203-208).

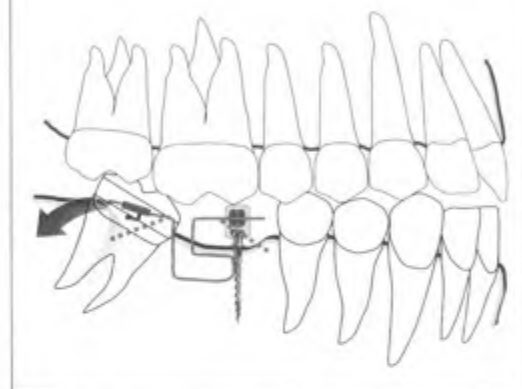
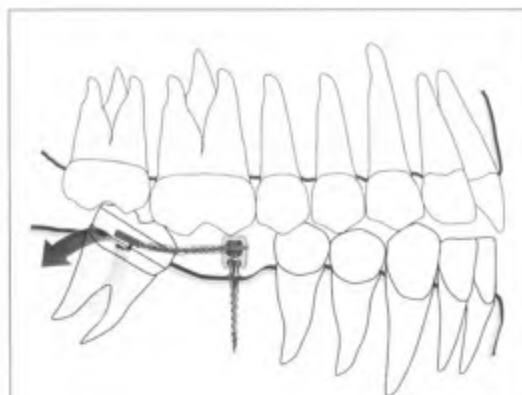




Sketch 5-36 Buccal mechanics for mini-implant supported intrusion.



Sketch 5-38 Molar uprighting using distal mini-implant and elastomeric chain.



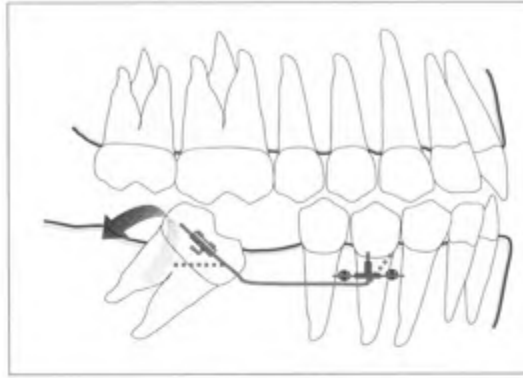
Sketch 5-37 Two options for uprighting of tipped molars using a mini-implant and composite retained band/bracket construction: mechanics using a compression spring on a segmented arch wire (sketch above) and using a TMA spring (sketch below). See also Case 35.

5.2.3.3 Uprighting of Tipped Molars

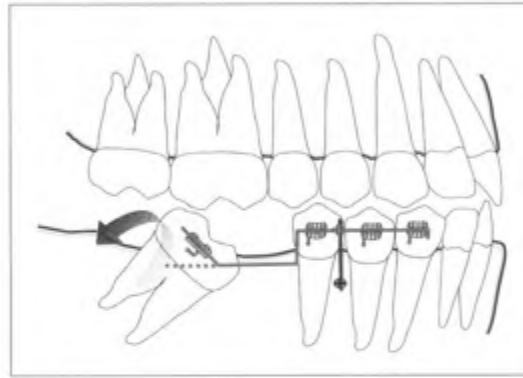
Uprighting of tipped molars without complete banding of all teeth is possible with mini-implant anchorage. When using mini-screws, no additional teeth, besides the tipped molars, need to have orthodontic appliances in place. The mechanics may consist of a compression spring on a segmental arch (Sketch 5-37, Case 35) that is supported by the mini-screw. Due to the coronal, eccentric force application, the molar experiences an uprighting moment. If the mini-implant is placed vertically, in the center of the alveolar process, attaching a segmental arch wire for uprighting proves to be difficult, unless a mini-implant with a bracket head design is used. An alternative would be to ligate or attach a small bracket to the head of the mini-implant using light-cured composite. Depending on the desired force system, a TMA-spring can also be chosen for uprighting mechanics. If, however, insufficient space is available between the tipped tooth and the adjacent tooth (molar severely tipped and/or migrated),

the mini-screw can be inserted distal to the molar. The molar is then uprighted using direct anchorage support for the elastic chain (Sketch 5-38). Unfortunately, there is often thick mucosa distal to the mandibular molars, requiring a long mini-screw. Another problem is that the elastic chain can slip and tear due to mechanical strain (i.e. mastication, functional excursive movements).

If there is too little space mesial to the molar to be uprighted, an interradicular implantation between the premolars is recommended. To avoid a torque load on the implant, either two implants are necessary, or one that will be coupled with an additional dental anchorage unit. If sufficient space is available for two implants, they can be connected by a segmental arch and direct anchorage can be established (Sketch 5-39, Case 39). If, for example, only one mini-implant is inserted, due to lack of space, the formation of an implanto-dental anchorage unit by integration of premolars is recommended (Sketch 5-40 and 5-41, Case 40).



Sketch 5-39, Case 39 Two mini-implants inserted between the premolar roots provide anchorage for molar uprighting. The mechanics consist of a specific TMA/NiTi spring that is connected to the implants using a segmented arch wire and a cross tube (photos by Dr. Müller-Hartwich, Berlin).



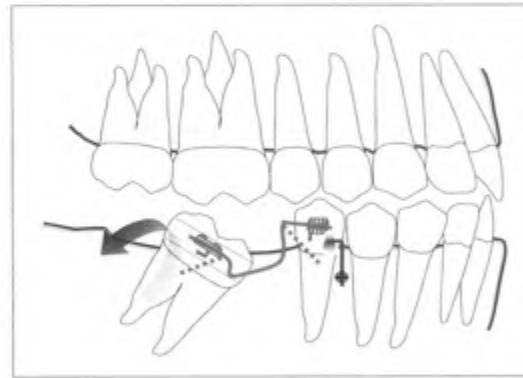
Sketch 5-40, Case 40 Using an implanto-dental anchorage unit for uprighting of the right second molar.

5.2.3.4 Mesialization of Posterior Teeth

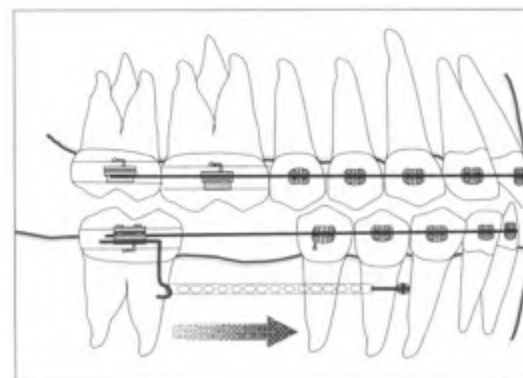
When mesial movement of the molar is required, sufficient anchorage is important to predictably achieve the desired effect, especially for mandibular molars. The two most common situations requiring mesial molar movement arise after the extraction of the first molars or when there is agenesis of premolars. Maximum anchorage for the anterior dentition is especially important for Class I or II malocclusions when no retraction of the anterior teeth is desired.

Direct Anchorage

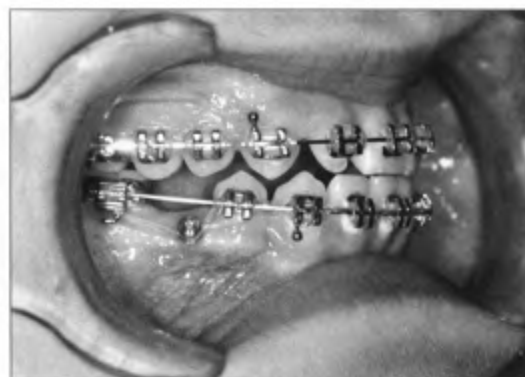
If direct anchorage is employed, then a mini-implant is inserted in the buccal alveolar process in the area of the premolars. A mesially directed force is applied by attaching a NiTi tension (open coil) spring or an elastic chain from the molars to the mini-screw. Forces applied to a Power-Hook at the molar can reduce friction to a certain extent (Sketch 5-42, Fig. 5-2). It is important to understand that the friction in the



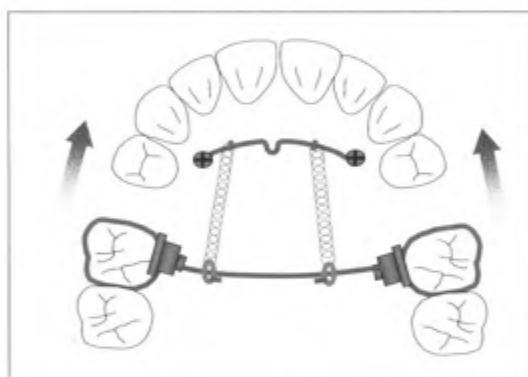
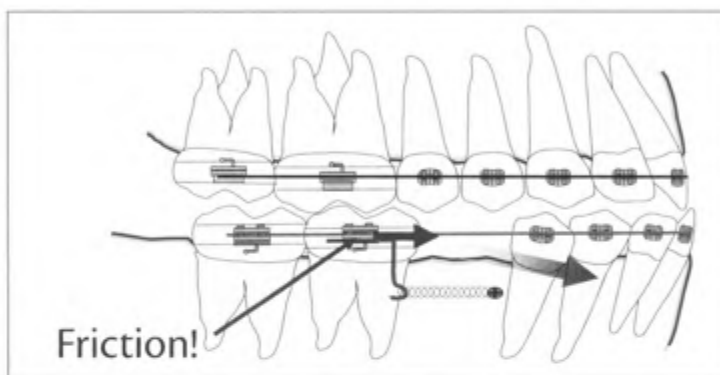
Sketch 5-41 Using an implanto-dental anchorage unit for molar uprighting. The mini-implant stabilizes the premolar through a stainless steel segmented arch wire and a light-cured composite connection.



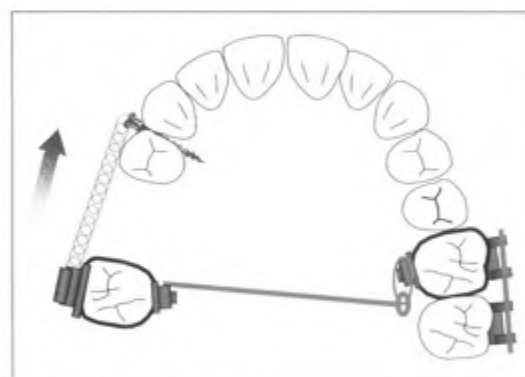
Sketch 5-42 Direct anchorage for molar protraction provided by a mini-implant in the premolar area. An elastic module creates the protraction force while a Power-Hook decreases friction and tipping.



Sketch 5-43, Case 43 Friction in the molar tube can lead to undesired mesialization of the main arch wire and thus to a protrusion of the anterior teeth.



Sketch 5-44 Maxillary molar protraction using two transpalatal arches, mini-implants and elastic modules.



Sketch 5-45 Unilateral molar protraction: a unilaterally attached transpalatal arch is used for rotational control. Mini-implant anchorage could be used in the top left quadrant as an alternative to banding the left molars.

molar tube can lead to unintended protraction of the main arch and result in iatrogenic protrusion of the front teeth (Sketch 5-43, Case 43). To prevent this effect, a wire ligature should be used to stabilize the anterior teeth against the mini-implant (e.g. tied to hooks on the canine bracket). It is important that the reactive forces of any mini-screw-supported mechanism be considered to avoid unexpected adverse effects.

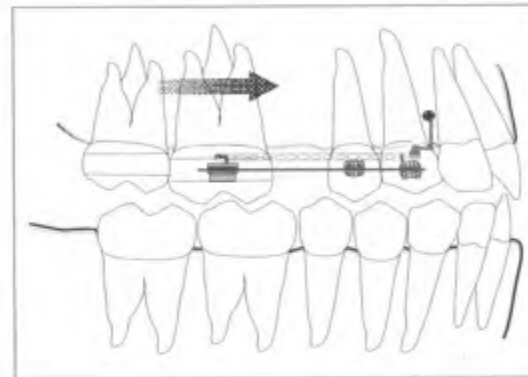
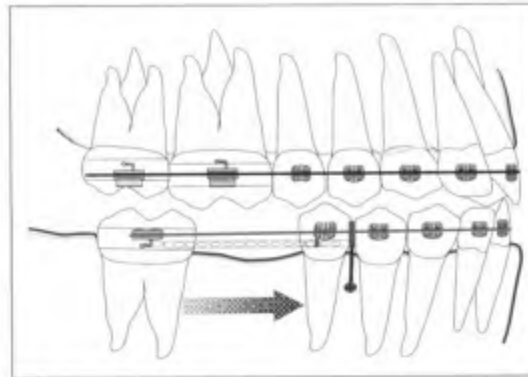
The palate can also be used as an insertion site for mini-implants (Sketch 5-44) for protraction mechanics. If unilateral mesialization with sec-

tional mechanics is desired, then a TPA can be used for rotation control (hinge mechanics) (Sketch 5-45).

Indirect anchorage

Molars can also be mesialized using indirect anchorage mechanics. The connection of a mini-implant to the dental anchorage unit can be accomplished using a short segmental arch in a cross tube on the base arch wire (Sketch 5-46) or by fixation with composite (Sketch 5-47).

Sketch 5-46 Indirect anchorage for molar protraction: the connection of the mini-implant to the dental anchorage unit occurs through a stainless steel segmented arch wire with cross tube.



Sketch 5-47, Case 47 Indirect anchorage for molar protraction: the connection of the mini-implant to the dental anchorage unit occurs through a stainless steel segmented arch wire and light-cured composite.

Anchorage with two mini-implants (Sketch 5-48, Case 48) is even more solid. See also anchorage of the anterior teeth in the horizontal level (section 5.2.1.1, Sketch 5-1).

5.2.3.5 Distalization of Posterior Teeth

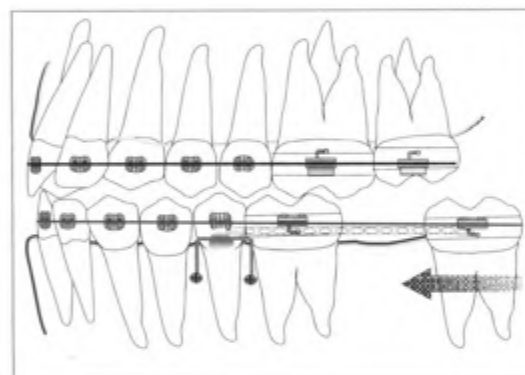
Mini-implants may also be incorporated into so-called "non-compliance" mechanisms for molar distalization (e.g. Distal Jet, Pendulum). Placement of mini-implants posterior to the molars is difficult due to unfavorable anatomic relationships in the retromolar region. In the maxilla, the limited bone quality as well as thick gingiva and, in the mandible, the tight space relations and the movable mucosa (posterior to the molars), limit distalization by simple tension mechanics.

A solution consists of more anterior insertion of the mini-implant and the use of pressure mechanics. Posterior teeth can be distalized using compression (open coil) spring, tube and wire ligature (Sketch 5-49). If the distalization is intended to be purely implant-anchored, the tube must not be clamped down on the arch so as to permit it to slide distally (see above: direct versus indirect anchorage). Indirect anchorage can be achieved by crimping the tube firmly. As an alternative, a wire ligature can also be tied directly to a bracket (Sketch 5-50).

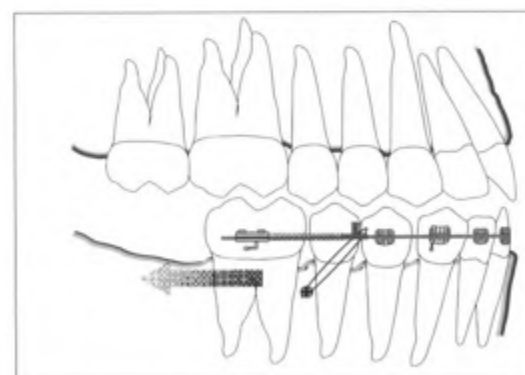
Should de-rotation occur during distalization,

vestibular pressure mechanics, using a mini-implant inserted in the anterior, can be used to achieve the desired treatment goal (Sketch 5-51, Case 51) without banding further teeth. As a result, spaces can also be opened for retained or impacted teeth. In addition, creating the appropriate space and root paralleling prior to prosthetic replacement of a missing tooth is also more predictable. When the entire posterior dental segments are to be distalized (e.g. to resolve anterior crowding), then the mini-screws may need to be removed and repositioned to a new location after molar distalization is completed; otherwise, the implant may interfere with subsequent retraction of the premolars. Unfortunately, this requires the cost of additional mini-screws and the associated procedures (Sketches 5-52 to 5-54).

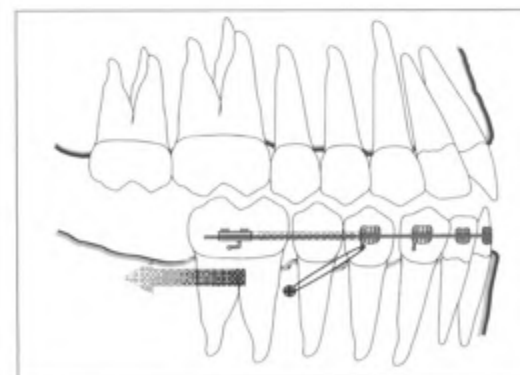
The reduced osseous quality in the maxillary retromolar region and the associated risk of implant migration may necessitate the combination of two mini-implants (Sketch 5-55, Case 55). In this instance, moving the implant is not required. Also, when inserting a mini-implant in the palate, a two-step approach can often be avoided due to the increased interradicular distance between molars and between molars and second premolars. Combinations of multiple implants and different mechanics are also possible (Sketch 5-56, Case 56).



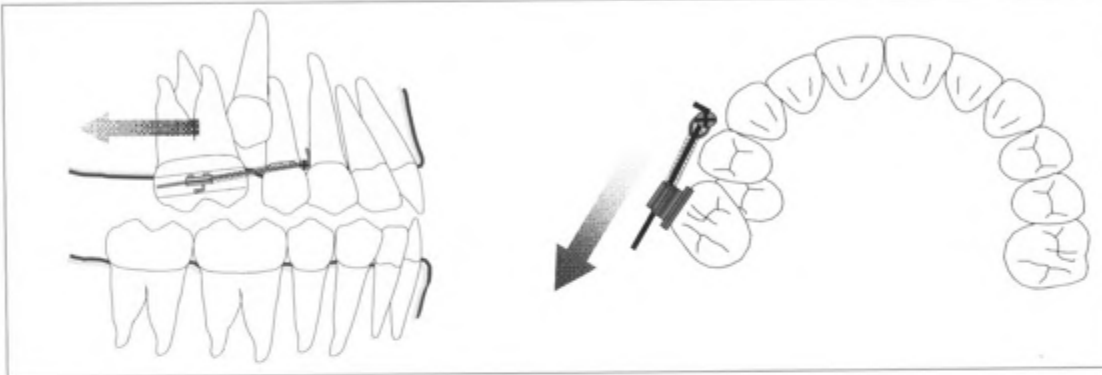
Sketch 5-48, Case 48 Indirect anchorage for molar protraction: anchorage consisting of two mini-implants, a stainless steel segmented arch wire and light-cured composite coupling is very stable (photos by Dr. D. Wiechmann, Bad Essen).



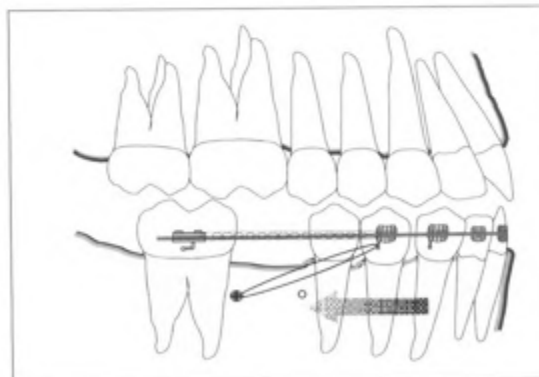
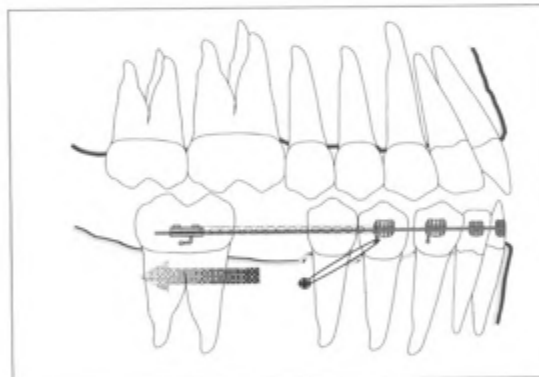
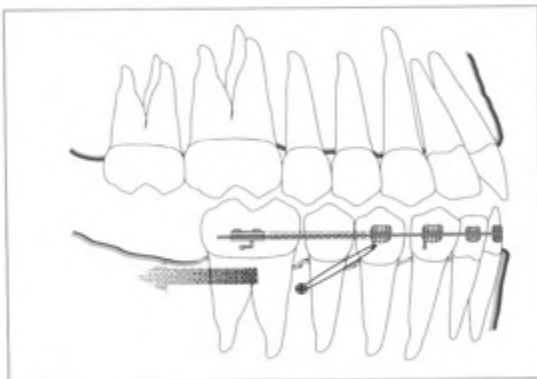
Sketch 5-49 Molar distalization using a compression spring, tube and wire ligature (see also Fig. 5-5). If the tube is crimped to the arch wire, the dentition will be integrated into the anchorage unit (indirect anchorage).



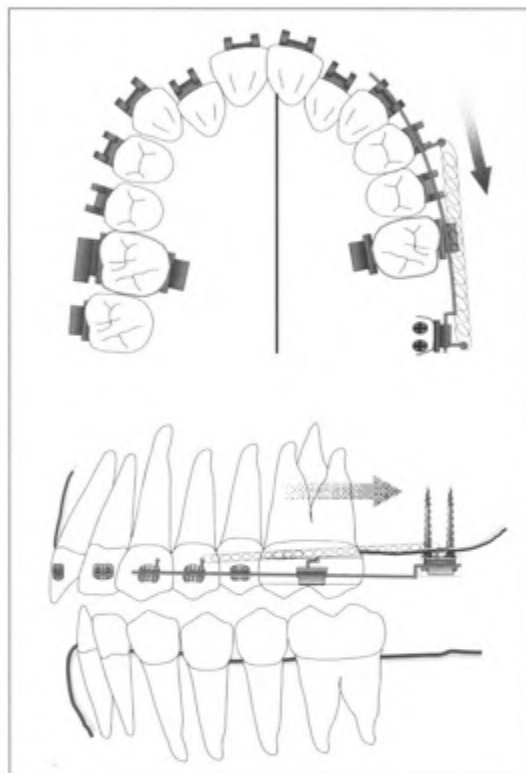
Sketch 5-50 Molar distalization using a compression spring (indirect anchorage): the premolar is connected to the mini-implant with a wire ligature, thus preventing mesial movement.



Sketch 5-51, Case 51 Distalization and de-rotation of the right molar using a 16 x 22 NiTi segmented arch wire and compression spring with mesially inserted mini-implant (Wilmes B, Rademacher C, Olthoff G, Drescher D. Parameters affecting primary stability of orthodontic mini-implants. *J Orofac Orthop* 2006;67:162-174).



Sketches 5-52 to 5-54 The entire buccal segment is being distalized in increments. This requires moving the implant after molar distalization (Sketch 5-53) because it otherwise will interfere with the premolar retraction.

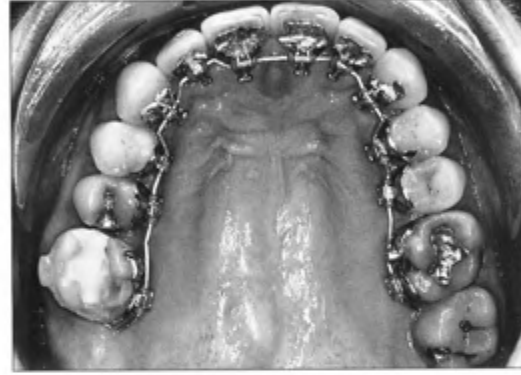
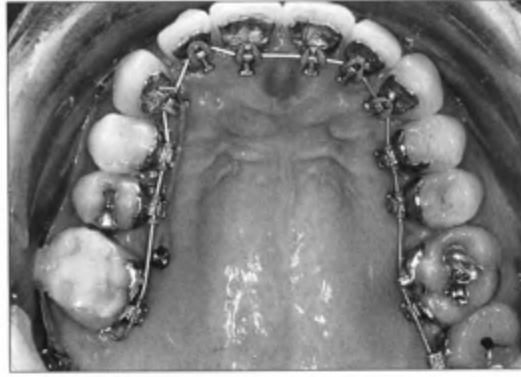


Sketch 5-55, Case 55 Molar distalization by coupling two mini-implants in the direction of force application using half a molar band and light-cured composite.

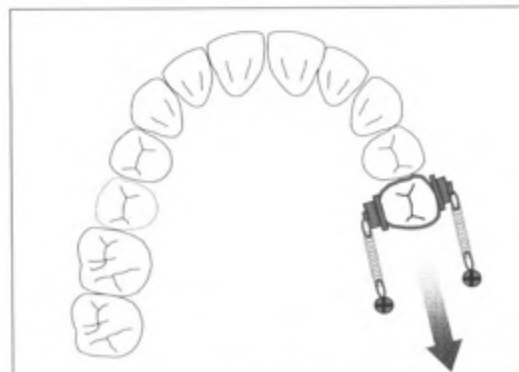
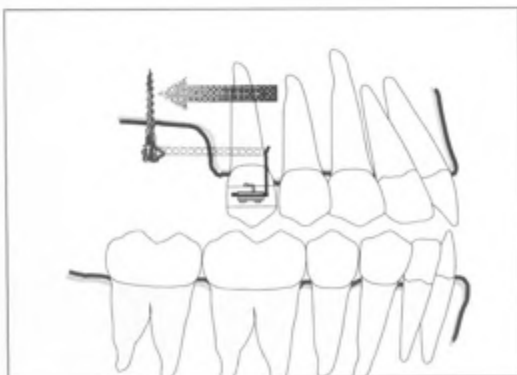
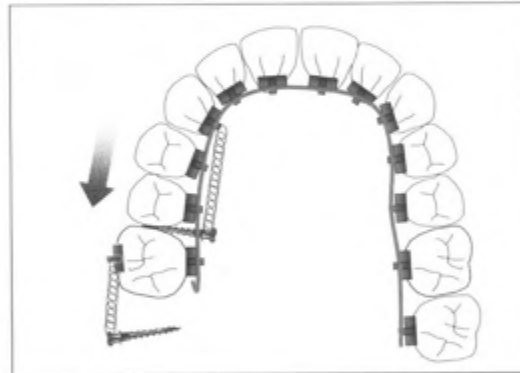
To reduce undesirable tilting or tipping, Power-Hooks or two mini-implants (vestibular and palatal) can be used, especially if the only teeth to be moved are banded (Sketch 5-57).

For maxillary molar distalization, mini-screws can also be inserted into the palate. The advantage here is that there is good bone and attached gingiva, along with the elimination of the risk of root injury. To reduce the risk of tipping or loss of the implant, the combination of

two connected mini-implants could be used here as well. Implant-supported modifications of the customary palatal distalization devices like the Distal Jet modification, Keles-Slider (Sketch 5-58, Case 58), Nance device (Sketch 5-59, Case 59) or the Dusseldorf Distal-Helix (Sketch 5-60, Case 60) are some possibilities. See Chapter 8, "Outlook", for an additional discussion of implant-based distalization mechanics.

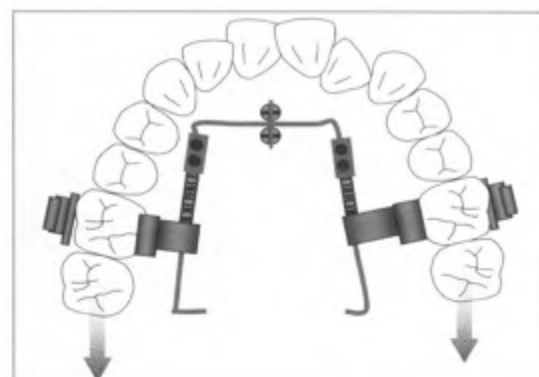


Sketch 5-56, Case 56 Distalizing the maxillary right buccal segment to correct a class II occlusion. Using lingual mechanics, a buccal and a palatal implant are inserted (photos by Dr. D. Wiechmann, Bad Essen).

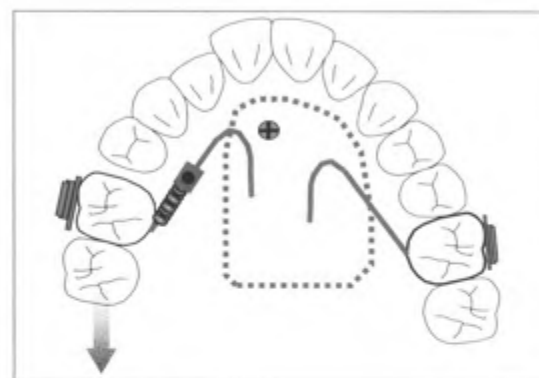


Sketch 5-57 Distalizing a second premolar to redistribute anchor teeth in preparation for a fixed bridge. To avoid undesired side effects, two mini-implants are used in addition to Power-Hooks.

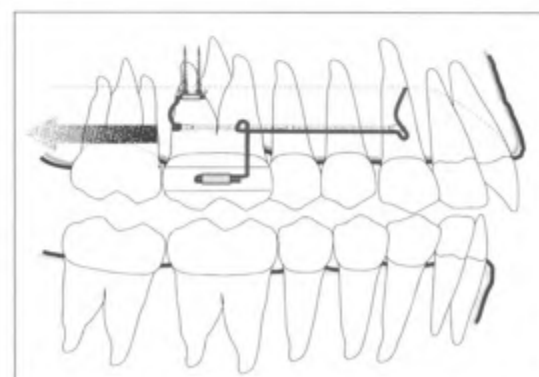
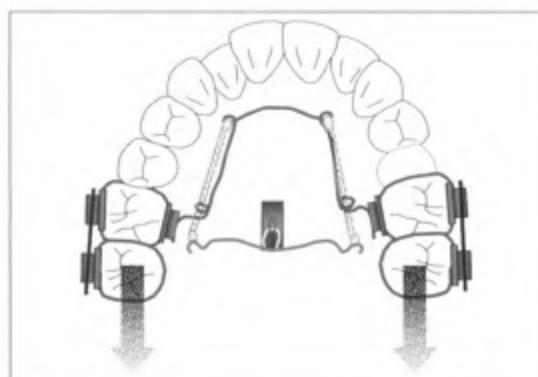
Sketch 5-58, Case 58 Maxillary molar distalization using the Keles-Slider: two mini-implants are blocked in the direction of force application to avoid anterior tipping.

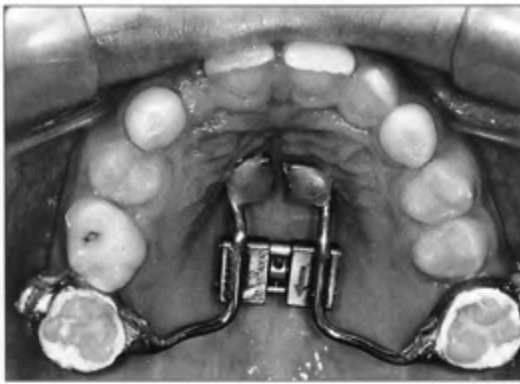


Sketch 5-59, Case 59 Distalization of the right molar with cortically anchored Nance button and Distal-Jet element (photo by Dr. B. Ludwig, Traben-Trarbach).

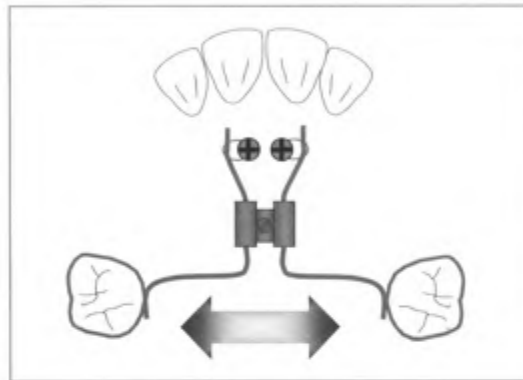


Sketch 5-60, Case 60 Maxillary molar distalization using the distal helix: two mid-palatal mini-implants are coupled in the direction of force application using half a molar band and composite to avoid tipping. A transpalatal arch is inserted in the soldered Mia-lock. Off this TPA, bilateral springs distalize molars that are connected through a Quadhelix.





Sketch 5-61, Case 61 Rapid palatal expansion using the Dusseldorf Hybrid-Hyrax: both first molars and two anterior mini-implants serve as anchorage.

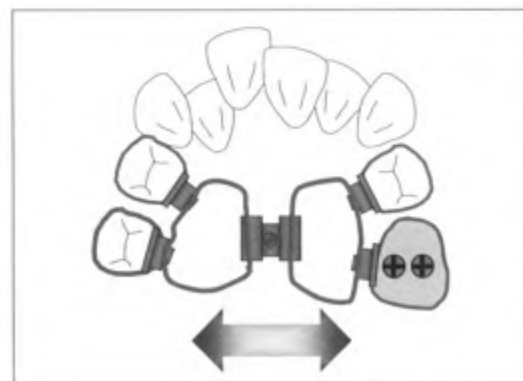


5.2.4 Dental Arch Coordination

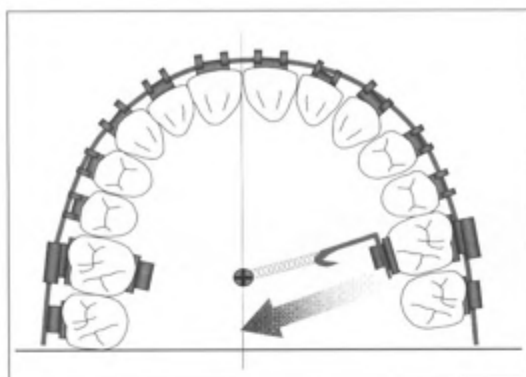
5.2.4.1 Palatal Expansion and Rapid Palatal Expansion (RPE)

Mini-implant anchorage can also be helpful in the coordination of the maxillary and mandibular dental arches. Rapid palatal expansion (RPE) is often indicated with a maxillary transverse constriction of skeletal origin. Sometimes, however, sufficient dental anchorage cannot be established and more tipping than sutural expansion results. A frequent reason for this can be the dental age. If the required deciduous teeth are mobile, during the late phase of the mixed dentition, adequate anchorage for continuous sutural maxillary expansion is not available. This is especially true when concurrent protraction of the maxilla is planned using a facemask, as waiting for complete eruption and root formation of the premolars is not desirable. An alternative mechanism would be to use the first molars in the posterior and two mini-implants for the anterior area as an anchorage for the Hyrax expander (Dusseldorf Hybrid-Hyrax, Sketch 5-61, Case 61).

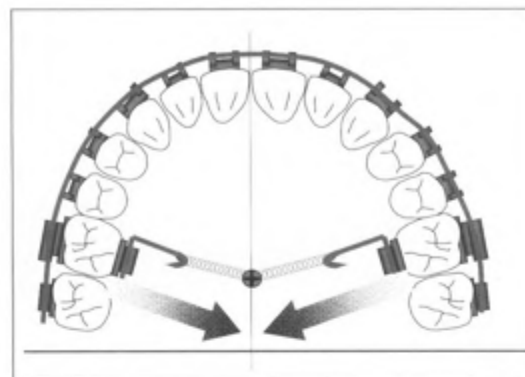
In the mutilated dentition (e.g. loss of first molars), mini-implants can be used to replace teeth as anchorage units. Since there is limited bony support in the posterior maxilla in these instances, two mini-implants should be inserted in the loading direction, next to each other, and then connected (Sketch 5-62).



Sketch 5-62 Rapid palatal expansion with reduced number of teeth: mini-implants connected with a molar band and composite in the direction of force application substitute as anchorage units for missing teeth.



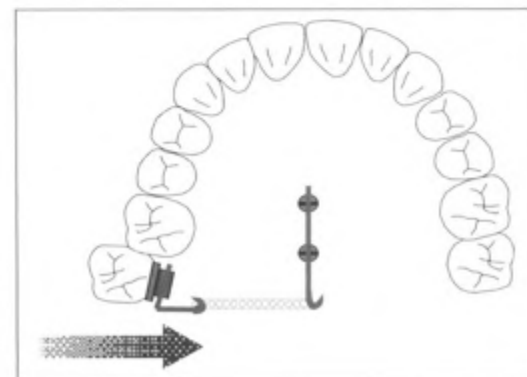
Sketch 5-63 Unilateral constriction of the dental arch using a midpalatal mini-implant, segmented arch and elastic module.



Sketch 5-64 Bilateral constriction of the dental arch using a midpalatal mini-implant, segmented arches and elastic modules.



Sketch 5-65, Case 65 Correction of a buccal cross bite between tooth 2 and 31 with a mini-implant anchored lever mechanic consisting of stainless steel segmented arches and elastic modules.



5.2.4.2 Transverse Dental Movements

An isolated, unilateral dental arch constriction is always a challenge with regard to anchorage supported by the contralateral side. Often, undesired side effects occur, in spite of anchorage bends (i.e. palatal root-torque). Mini-implants inserted in the area of the median palatal suture can provide the necessary anchorage (Sketch 5-63).

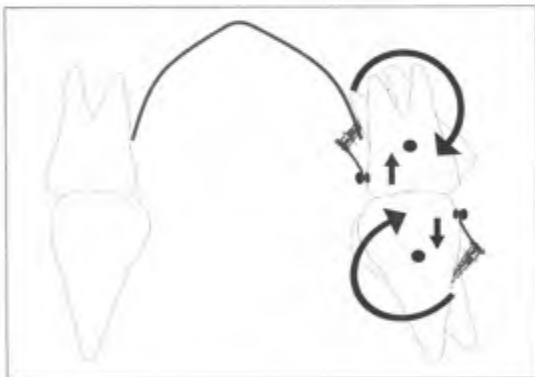
Bilateral arch constriction can also be achieved with mini-implant anchorage (Sketch 5-64). In this case, an intrusive force component can be regarded as an advantage compared to traditional anchorage when correcting a buccal crossbite (i.e. so-called "Brodie bite"). The medial movement of individual teeth is also possible (Sketch 5-65, Case 65). As already mentioned, the insertion of two mini-implants may be necessary, in particular for second molar movement, in order to achieve the desired force direction while simultaneously avoiding unfavorable torque on the implants. The palatal alveolar process is also theoretically a possible insertion site. One disadvantage is the rather short distance between the tooth and implant head, which adversely affects the function of elastic elements connecting them (Sketch 5-66).

If the lower molar is tipped lingually in a buc-

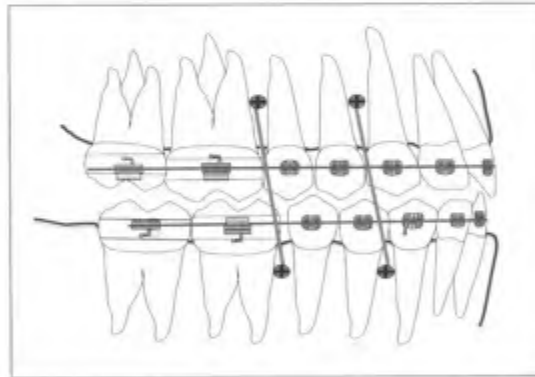
cal crossbite, an intrusive and buccally directed force system can be generated using mini-implant anchorage. The correction of a crossbite would generally be possible using inverse implant positions: buccal in the maxilla, lingual in the mandible

5.2.4.3 Corrections in the Sagittal Plane and Vertical Dimension

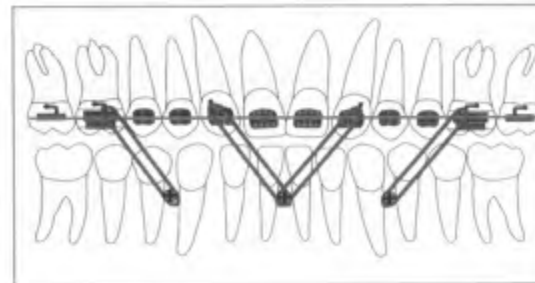
If intermaxillary elastics are worn against mini-screws, substantial intermittent forces are generated. Present research suggests that mini-implants have a better prognosis with lighter, continuous loads. Accordingly, implants should have a diameter as large as possible and the duration of force application should be limited if they are to anchor intermaxillary elastics. Routine correction of a Class II malocclusion for an adolescent, using mini-implant anchored elastics, seems ill advised. In contrast, short-term elastic wear for intermaxillary fixation after orthognathic surgery seems reasonable, especially if both jaws are not completely banded and/or the dentition itself is not to be loaded (Sketch 5-67). The coordination of the dental arches by banding of only one jaw is another possible indication for mini-screw anchorage support (Sketch 5-68, Case 68).



Sketch 5-66 Correction of a buccal cross bite (Brodie bite) using mini-implant anchorage: mini-implants inserted on the palatal in the maxilla and on the buccal in the mandible. The resulting intrusive component is advantageous.



Sketch 5-67 Intermaxillary fixation post orthognathic surgery using mini-implants.



Sketch 5-68, Case 68 Dental arch co-ordination using mini-implants when banding only one arch after canine substitution in a lateral incisor agenesis case (photo by Dr. B. Ludwig, Traben-Trarbach).

5.3 Conclusion

From examining the case reports and descriptions in this chapter, it is quite apparent that the application of mini-implants with traditional orthodontic mechanisms and devices presents substantial opportunities for inventiveness and innovation. However, careful planning is necessary to avoid unintended side effects. Traditional orthodontic "tooth regulation" has been dramatically altered forever by the advent of mini-screw anchorage.

5.4 References

1. Wilmes B, Drescher D. Verankerung mit Miniimplantaten bei präprothetischer kieferorthopädischer Therapie. *Kieferorthopädie* 2006;3:203–208.
2. Wilmes B, Rademacher C, Olthoff G, Drescher D. Parameters affecting primary stability of orthodontic mini-implants. *J Orofac Orthop* 2006;67:162–74.

Risks and Prevention Strategies

Cortical anchorage techniques use the peri-implant bone for anchorage and in doing so intervene into an autonomous and intact system. In contrast to other surgical interventions that may be curative or corrective in nature, no primary or indispensable necessity exists to penetrate osseous structures for orthodontic reasons. Here the objective is to safeguard and optimize treatment procedures. Orthodontist and patient must agree on this minimally invasive procedure for specific and deliberate reasons. Motivation for using mini-screw anchorage may result from personal desires, reduction in discomfort that may be associated with other alternatives (e.g. headgear, surgery), reduction in treatment time and more predictable results. These factors are very important, especially in the treatment of adults.

The application of mini-screws in orthodontics is characterized by a favorable risk-reward ratio due to the small dimensions and relatively simple insertion of these devices. Nevertheless, it is a surgical procedure, and, as such, shares the same risks and complications known for prosthetic implants.

Mini-screws can be inserted in dental practices and every specialty branch. Dentists, periodontists, and oral surgeons are familiar with comparable treatment methods; therefore, they may only need to get acquainted with details of a specific mini-screw system. Orthodontists have typically had less contact with surgical techniques in their specialty education and may want to consult with colleagues experienced in implantology prior to attempting mini-screw placement.

If risks, complications, and their origins are known and can be assessed, they can certainly be avoided for the most part. In this respect, a classification of different therapeutic and tech-

nical steps should be helpful. It is obvious that many factors overlap and influence the success and the risk of the treatment method with mini-screws at different times. Thus, for example, the premature loosening of a mini-screw can depend on operator technique and experience, on the screw system, and also on the patient. Multiple reasons for mini-screw failure have been described: pre-surgical factors (e.g. choice of insertion site), intra-surgical factors (e.g. insertion trauma) and post-surgical factors (e.g. excessive loading of the implant).

Every treatment procedure, especially if invasive, includes some degree of risk of complications or undesirable side effects. The risk to the patient, measured as a function of treatment outcome, should be as minimal as possible. To achieve this objective predictably, the potential reasons for risks, as well as strategies for their avoidance or reduction, must be known. The objective of this chapter is to explain the most important reasons for potential risks and failures, as well as to present solutions to prevent such problems. Because effects and side effects, as well as mechanical action and reaction, are inseparable, some aspects from previous chapters will be reflected upon again with reference to the inherent risk potential. In this sense, this chapter offers a summary and overview of the application of mini-screws for cortical anchorage in orthodontics.

6.1 Technical and Physical Criteria

The choice of mini-screw system is the first step for the routine application of mini-implants in clinical practice. Technical and physical parameters determine this choice. The range of prod-

ucts on the market is extensive, as shown in Chapter 3, and encompasses a variety of philosophies (see also Table 3-10). The decision to select a mini-screw is usually made once, prior to initial application, and, in part, determines the treatment plan from that point forward.

In connection with the detailed descriptions of systems and products in Chapter 3, the most important parameters that influence the risk potential are reviewed here.

The mechanical value of a mini-screw depends on its construction material, the relation of the functional components to each other and the thread design (i.e. diameter, shape and taper). These technical factors influence the product's primary stability, load limits and survival rate.

Most mini-implants are fabricated from titanium alloy TiAl6V4. These alloys possess more favorable mechanical properties in terms of firmness, elasticity and wear resistance when compared to pure titanium (see Table 3-1). The elastic limit of titanium alloy is clearly higher, which allows filigree partial structures, like the turn of the thread, to be fabricated solidly^{62,63}. In this manner, the risk of material fatigue during insertion and activation is reduced.

As an alternative to titanium, only one high-grade steel mini-screw is available. Steel appears to be more resistant to material failure than pure titanium⁷. Steel alloys are bio-tolerated materials (i.e. can be inserted in the bone), and may result in distant osteogenesis⁶⁴. However, there is no direct contact between the implant and the bone, as the gap between them is filled by connective tissue. According to the manufacturer Leone (Florence, Italy), this implant can be more easily removed after treatment due to this fibrous encapsulation.

Mini-screws with small inner core diameter (i.e. the implant shank without the thread layer) have reduced resistance against material fatigue and torsion. It is important to understand how diameter is measured by the manufacturer, as it may refer to the inner core (shank) diameter or outer core (thread) diameter, and there are potential implications for either alternative.

During insertion, the greatest stress is exerted on the mini-screw when perforating the cortical bone. Implants with an outer core diameter smaller than 1.5 mm fail more quickly under torsion and bending stress⁶⁵. As a result, mechanical anchorage and, ultimately, clinical success is less reliable⁶¹. For implants with an inner core diameter of 1.2 mm or less, pre-drilling (at least

through the cortical bone) has been recommended to reduce material stress.

After insertion, mini-screws achieve their stability primarily through mechanical anchorage in the adjacent bone. The anchorage capacity is influenced by the entire surface area of the mini-screw contacting bone⁶⁶: the length and the diameter of the implant. It should be noted that a distinct relationship between implant length and diameter exists. With reduced length, the diameter can be accordingly small and vice versa. In general, the diameter and not the implant length is the most important factor when it comes to retention in the bone⁶⁷.

During mini-screw insertion, the surrounding bone will be displaced and compressed. The degree of compression largely depends on the shape of the implant core or shank. Cylindrical shanks produce a continuous amount of bone compression over the total length of insertion. The torque, therefore, remains at a constant level during the insertion process.

Conical shapes exhibit increasing insertion torques during placement, thereby applying differential stress to the bone structures. At the end of the insertion, tissue compression is at a maximum, bringing about a design-specific peak in torque. Conical implants are at an advantage in anatomically narrow areas (e.g. interradicular)⁷. The reason for selecting a conical implant shank (as derived from prosthodontics) is the "tight fit" due to the compression. This effect has a positive impact on primary stability. However, in contrast to conical prosthodontic constructions, the thread is interspersed with smooth surfaces for mini-screws. Consequently, cylindrical mini-screws tolerate greater loads than conical ones. Fig. 6-1 demonstrates implant shanks in schematic form (designed for skeletal anchorage) that clearly differ in construction, design and mechanical properties.

6.2 The Patient

6.2.1 Anamnestic Criteria

It is advised that general and specific health history, including all diseases that are known to increase the risk for post-surgical complications, be taken for each patient in a standardized format. Systemic, metabolic and hematologic diseases, infectious diseases, medication and allergies may determine therapeutic limits²⁹.



Fig. 6-1 Implant shanks in schematic form differing in length, diameter, and thread design.

Systemic Diseases

Basic systemic diseases can affect bone metabolism and its regenerative potential. This may increase the risk for peri-implant infection and premature loss of the implant. At the same time, an overall risk assessment of the patient's general health has to be considered. In patients who are at risk for endocarditis, an iatrogenically induced bacteremia can assume life-threatening dimensions. Therefore, all therapeutic measures that could result in exposure into the bloodstream may require adequate antibiotic prophylaxis coordinated with the physician in charge^{35,47}.

In women, potential osteoporotic processes must be taken into consideration. According to international calculations up to 15% of all women are affected, and with increased age the prevalence rises to 30% up to 65%⁴⁷. In these patients the osseous density decreases progressively by widening of the medullary cavities and changes in bone micro-architecture. Strength and resistance of the cortical bone decrease⁴¹. Although osteoporosis can lead to increased resorption of the alveolar bone, studies show that the survival rate of implants is generally not affected³². It is important to note that women taking bisphosphates to reduce osteoporosis have been recently identified as poor candidates for most orthodontic procedures.

For forensic reasons, however, the patient should be thoroughly educated on their particular and individual situation.

Metabolic Diseases

Diabetes mellitus is no longer a rare and late-appearing metabolic disease. Due to our present-day lifestyle, more youngsters exhibit this disease. Different studies have shown that patients with well-controlled diabetes, compared with healthy patients, exhibited a slightly reduced survival rate for implants⁵³.

There are also restrictions before and during mini-screw insertion that may require consultation with the family physician^{21,54}. Even in a normal situation, the risk for infections is increased when a mini-screw is inserted. Wound healing and osseous metabolism are reduced by vascular deformations in the form of microangiopathies and arteriosclerosis. Today, these changes are classified as a basic element of the clinical picture.

Local anesthetics with epinephrine additives should not be used for these patients. Placement after ingestion of food is to be preferred, because stress situations resulting from surgical measures can trigger a metabolic crisis.

Patients with diabetes often suffer from xerostomia and neurological pain that can manifest itself orally in the form of pruritus, burning, numbness and pain. Before treatment with fixed appliances of any sort, the possibility of altered sensitivity and a general tendency for irritations and sore spots must be explained.

Hematologic Diseases

Hemorrhagic diatheses cause an increased disposition for bleeding either originating from vascular, thrombocytic or plasmatic problems. After superficial injuries, patients with vascular and thrombocytic forms show a tendency for increased and extended bleeding, as well as a disposition to form hematomas. Plasmatic blood coagulation disturbances, caused by the lack of different coagulation factors, can lead to uncontrolled bleeding that could lead to emergency situations^{32,66}. The risk of inserting mini-screws in these situations would probably preclude their use.

Systemically Effective Drugs

Systemic effects, side effects and drug interactions must be observed¹⁷, especially for patients

who require long-term medication. Patients taking phenytoin- or nifedipine-based drugs often develop a peri-implant hyperplasia of the mucosa, that as a result of a secondary inflammation can lead to the loss of implants¹¹⁶⁴.

Special care is necessary with patients who take anticoagulants⁶⁹ (e.g. aspirin), as there is an increased risk of post-surgical secondary hemorrhage. Normal blood coagulation is to be expected only several days after discontinuing the medication. Ibuprofen also extends the prothrombin time and inhibits the aggregation of thrombocytes. With a long-term antibiotic therapy, the formation of coagulation factors can also be reduced by a temporary reduction of the vitamin K balance⁶⁶.

Allergies

In a dental-medical anamnesis, patients most often indicate incompatibilities and allergies to certain analgetics, antibiotics, local anesthetics and dental materials. From the patient's point of view, "allergy" is an extensively defined term. Often, arising dysesthesias are valued as manifest allergic reactions. Real allergies show at least one of the classical allergically conditioned symptoms. The dentist should ask precise questions for certain diagnostic criteria such as swellings, exanthemas, urticarias, conjunctivitis, rhinorrhea, dyspnea, and thoracic oppression⁶⁶.

Allergic reactions arising from the insertion of mini-screws can be predominately attributed to the administration of local anesthetics³⁰. Articaine, prilocaine and lidocaine only rarely cause hypersensitivities. With the ester linked local anesthetics like procaine and tetracaine, allergic reactions of the immediate type arise during the hepatic degradation of the active substance. Procaine is also hydrolyzed to PABA, a folate precursor, and can interfere with the antibacterial effect of sulfonamides. Increasing incompatibilities of added preservatives, if disposition exists, may cause severe physical reactions including anaphylactic shock⁶⁶.

The risk of sensitization by the implant material itself is generally low⁶². Titanium and titanium alloys are characterized by their high corrosion resistance and also by excellent biocompatibility. An oxide layer is formed when these metals are in contact with oxygen and tissue fluid, and it has a passivation effect. Even if mechanical damage occurs, the superficial corrosion barrier regenerates within millisec-

onds due to the strong affinity to oxygen and nitrogen. Corrosion phenomena, however, can be found under the influence of acidic, fluoride-containing prophylaxis agents⁷⁰. Although titanium ions are generally released only in very small quantities, they could be traced both *in vitro* and *in vivo* in test organisms and in the surrounding bone. A valid medical assessment of this phenomenon does not exist and is not yet foreseeable; however, decades of positive clinical experiences in the field of dental implantology are a sign of their safety⁶.

Lifestyle

It is important to understand that concealed or understated habits can jeopardize the success of treatment by reducing or impeding the expected treatment response. Studies from dental implantology²⁴⁹ prove that smoking is a serious risk factor that is associated with post-operative problems such as impaired wound healing. In smokers the resorption rate of the peri-implant bone increases in the area of the implant³¹. Mechanical manipulation (e.g. the tongue or the fingers playing with the implant) of a mini-screw can loosen it and may result in premature loss of the device.

As with every conventional orthodontic treatment approach, adequate oral hygiene is required. The attention of the patient should be drawn to the necessity of cleaning the implant head, especially as it is positioned far away from the teeth, where tooth brushing is habitually accomplished.

Growth Inhibition

In the case of palatal insertion in adolescents, possible effects on growth and development potential exist (Fig. 6-2).

Different studies on children with ectodermal dysplasia show that implants do not contribute to a sagittal and transverse growth inhibition of the alveolar bone¹⁸⁶⁵. Nevertheless, to avoid possible growth inhibition the skeletal age should be taken into consideration and, if necessary, a paramedian positioning of the mini-screw should be chosen⁶².

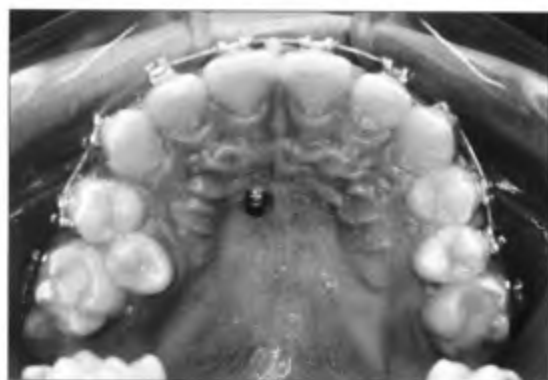


Fig. 6-2a Paramedian screw position characterized by avoidance of suture and employment of two anchorage elements.



Fig. 6-2b Median screw position with potential growth complications in the region of the suture.

Fig. 6-2 Palatal insertion of mini-implants in adolescents.

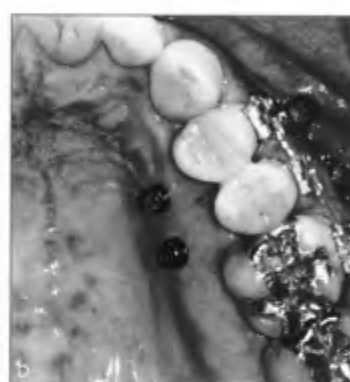


Fig. 6-3 Favorable screw positioning in well-supported compact bone; ideally detached from nearby structures.

6.2.2 Morphological Criteria

If no general contraindications are known, intra-oral relationships are to be evaluated (see Chapter 5). Favorable conditions generally exist where tightly keratinized gingiva⁸ and morphologically well-structured compact bone are found (Fig. 6-3)^{9,10}.

The anchorage capacity of a mini-screw directly correlates with the quality and the amount of osseous support and is limited by the surrounding osseous relationships. From anatomical studies, the osseous architecture of the respective jaw segments is common knowledge for dentists. However, individual deviations from the norm can occur and are not specifically traced simply to the effects of specific pre-existing illnesses. Therefore, the evaluation of radiographs should be completed to further evaluate the cranial and facial morphology. The diagnosis of the skeletal jaw relation may add information on the osseous situation to be expected. Patients that have a skeletal Class III malocclusion (with mandibular prognathism) of-

ten exhibit compact, well-dimensioned osseous areas in the region of the anterior mandible, and wide interradicular septas in the molar and premolar region. It may also be assumed that a generally stronger developed cortical bone exists as well. In a skeletal Class II patient, antidiromic conditions can be expected in the mandible. For the Class II Division 2, more osseous support and insertion areas are found in the direction of the apical base of the maxilla.

A desirable mini-implant site can best be determined by model analysis, clinical evaluation of the mucogingival junction and the course of the palatal rugae. These are more important in the site selection process than the evaluation of a two-dimensional radiograph. Apart from the lingual aspect of the mandible³ and the region around the tuber, all other jaw areas have proved clinically successful for the insertion of mini-screws. In general, the insertion is easier in the maxilla than in the mandible due to the osseous structure, in particular the thin cortical bone. The most favorable anatomic zones (within the attached gingiva) are the interradic-

ular septas (especially mesial of the first molars) and the osseous structures of the hard palate. The area of the tuber has an especially thin cortical bone and, therefore, offers little anchorage value⁸³⁹.

According to a recent study by Park⁸⁴⁰, adequate mini-screw stability can be achieved in the maxilla when using pre-drilling in all examined cases. However, according to a study by Berens et al⁸⁴¹, all mini-screws inserted in the lingual mandible were lost by primary or early secondary stability deficits.

In proximity to dental follicles and deciduous teeth, the osseous structure is mostly dispersed and likely inadequate to support a mini-screw. A similar situation exists in recent extraction sites where sufficient time for regeneration of the bone should be allowed.

6.3 Iatrogenic Risk Potential

As with all medical interventions, every surgical procedure exhibits a certain risk potential that, as a rule, can be minimized or avoided by suitable planning and preparatory measures. Risk factors can be divided into a pre-, intra- and post-surgical phase.

6.3.1 Pre-surgical Factors

The insertion of a mini-screw must be carried out according to hygienic guidelines for general surgical interventions. The implant systems to be applied should also be selected in respect to hygienic delivery forms (packaging and dispatch procedure). Some manufacturers offer their mini-screws in sterile packaging or in sterilizable boxes in which the accessories can also be processed hygienically. Mini-screws that are pre-sterilized by the manufacturer demonstrate a high degree of surface purity, in particular in the area of the thread. A contaminated implant could be a possible reason for premature loss. Sterility and a surface free of particles and endotoxins are a prerequisite for reliable integration of the mini-screw into bone.

All associated, invasive instruments (e.g. pilot drill, mucosa punch) must also be disinfected, cleaned and sterilized before application. To fulfill this demand, pre-sterilized, but disposable, products can be used (see section 3.5.1). It is important that local hygiene regulations must be

followed. For example, in Germany, these are the RKI guidelines (Robert-Koch-Institut).

6.3.2 Intra-surgical Factors

Apart from a few exceptions, orthodontic anchorage implants are inserted monocortically. They vary in length between 4 and 12 mm and in diameter between 1.2 and 2.3 mm depending on the system.

Near some potential insertion sites in the maxilla are some anatomical sites of interest, such as the *Nervus palatinus major*, the *Nervus nasopalatinus* (*Nervus incisivus*) and the *Arteria palatina major*. In the mandible, potential problems may arise due to the location of the *Nervus alveolaris inferior*, the *Nervus mentalis*, the *Arteria alveolaris inferior* and the *Arteria mentalis* (Fig. 6-4). The potential risk for damage of the *Nervus alveolaris inferior* is generally estimated as very low in the permanent dentition and with normal jaw relations. This applies in similar fashion for the *Arteria palatina*, even if some authors⁸⁴² have described nerve and vascular injuries from dental implants as a dangerous and possibly life-threatening complication.

With substantially pneumatized maxillary sinuses or advanced resorption of the alveolar process, a perforation of the *maxillary sinus* (Fig. 6-5) is possible. The risk of a maxillary sinus or nasal base perforation can be limited by precise radiological diagnostics with the help of the panoramic radiograph, or if necessary by means of computerized tomography. Cone beam computerized tomography (CBCT) offers the same advantages as conventional CT imaging but with reduced levels of radiation.

Complications after perforation of the maxillary sinus, including suppurative sinus infections or fistulization, were described only for dental implants in the literature⁸⁴³. Nasal base perforations have been mentioned in the literature for dental implants only and they seem to heal without difficulties⁷².

In the interradicular area, the spatial relations of adjacent roots and dental follicles must be evaluated⁴⁹. For pre-surgical planning, some manufacturers recommend radiological diagnostics over X-ray-visible positioning stents⁸⁴⁴. Indeed, vertical and horizontal distortions resulting from skewed projection can lead to false evaluation of the intraosseous spatial relations (see Chapter 3, Fig. 3-15)^{48,63}.

Fig. 6-4 Anatomical position with regard to nerve tracts and vascular structures.

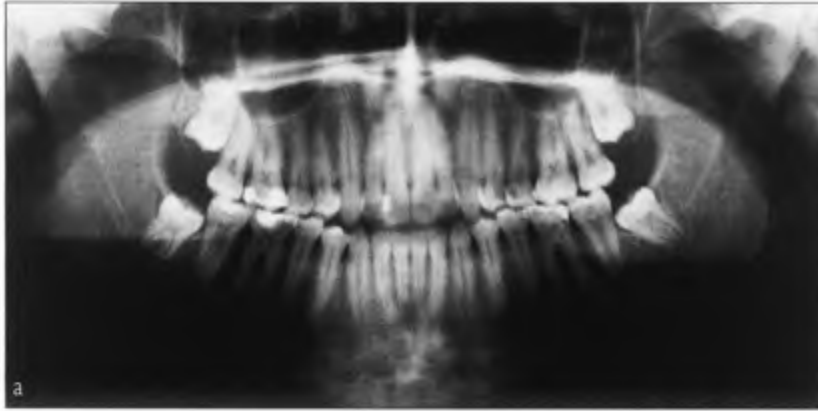


Fig. 6-4a Radiological illustration of the mandibular canal, which contains the mandibular nerve and vessels and exits at the mental foramen (apically of the first and second mandibular premolars). Generally the distance from the mandibular canal to the root apices of the teeth is 1–2 mm in the molar region and 2–3 mm in the premolar region. Because the mandibular canal can present with marked individual variation – even interradicular pathways have been documented – individual diagnostic imaging is recommended.

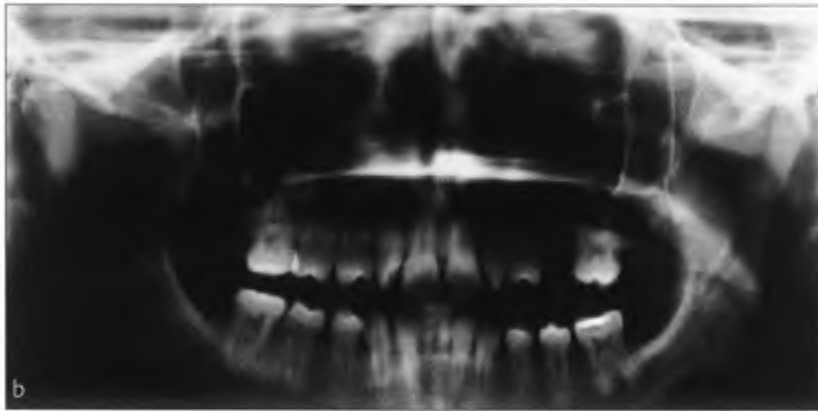


Fig. 6-4b Unexpected high pathway of the mandibular canal due to atrophic changes in the bone. The position of the nerve/vessels must be interpreted relative to the surrounding structures.

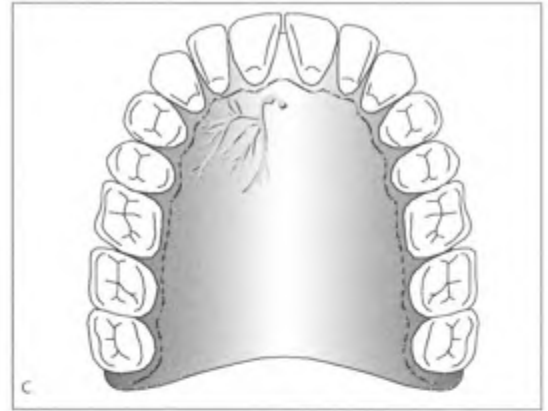


Fig. 6-4c Pathway of the nerves/vessels at the incisive foramen.



Fig. 6-4d Pathway of the nerves/vessels at the palatine foramen.

When manually inserting self-drilling mini-screws, pre- and post-operative radiographs may not always be required, thereby reducing X-ray exposure. This is because the risk of root injury is reduced due to tactile feedback. In other words, the operator can often “feel” it if a root is touched as resistance increases dramatically. The use of the self-tapping mini-screw (those that require pre-drilling) is more of a concern in this respect as root injury during the pre-drilling process is less noticeable to the clinician as the tactile sensation is reduced. Both implant designs (self-drilling and self-tapping) carry the risk of an unintentional change of direction during insertion. For self-drilling systems, the ideal path of insertion may be diffi-

cult to maintain due to the hardness of the cortical bone that needs to be penetrated. For self-tapping systems, the angle of insertion of the pilot drill should not be altered during the drilling process. For more information on this see also section 3.3.4.

The insertion of a mini-screw can usually be done with only topical anesthesia, because only gingiva and periosteum are innervated. The sensitivity of the periodontium will be preserved and can provide feedback on the insertion direction via active nociceptive pathways. In other words, the patients will likely report if a mini-screw touches a root as they will feel it. A post-surgical radiograph may provide only limited information about the success of the per-

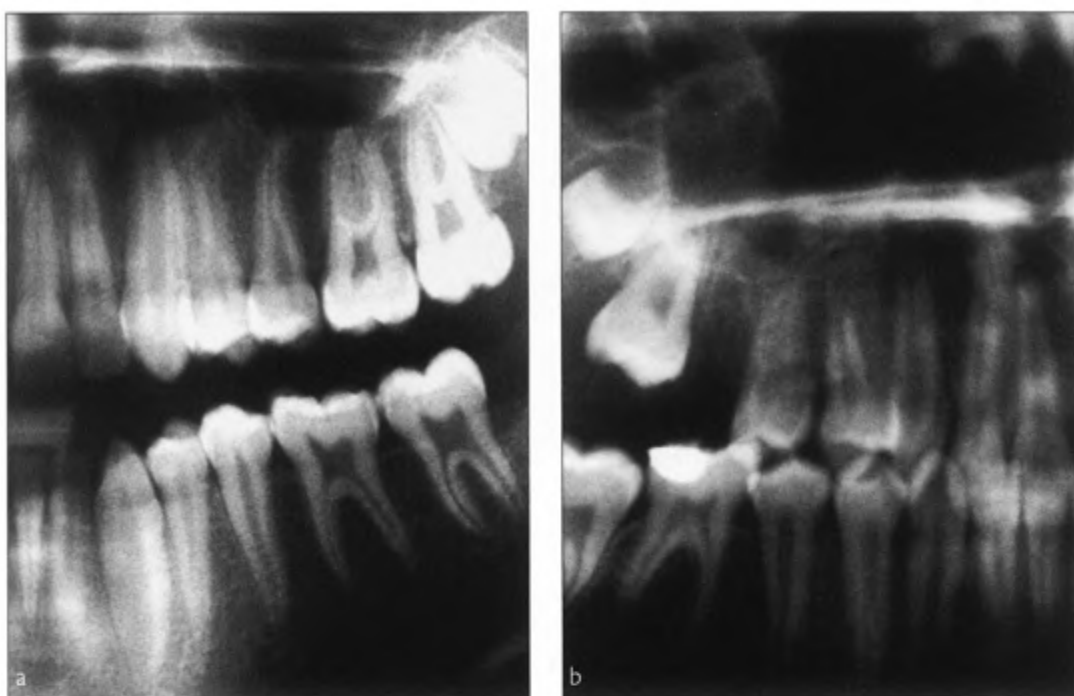


Fig. 6-5a and 6-5b Panoramic radiograph indicates well-structured compact bone and simple maxillary sinus.

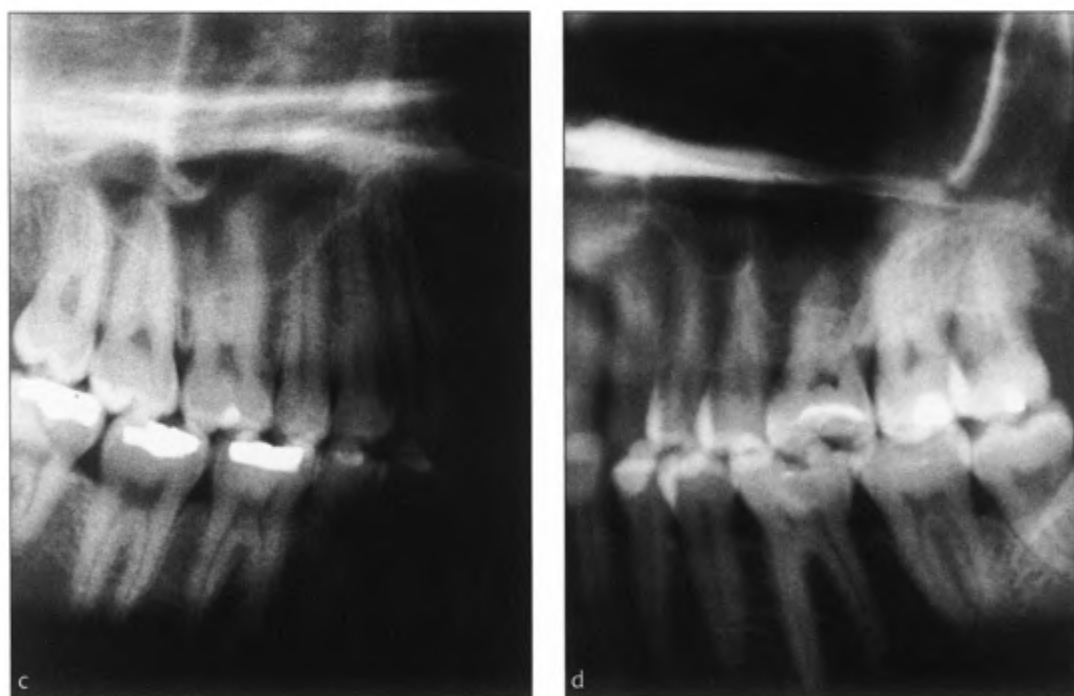


Fig. 6-5 Extract from orthopantomogram in the region of maxillary sinus: radiological diagnosis.

Fig. 6-5c and 6-5d Panoramic radiograph indicates complex maxillary sinus structures.

formed procedure due to the well-known inaccuracies associated with bitewing or periapical radiographic techniques (Fig. 6-6).

If the implant does damage adjacent dental structures during the insertion, the injured surface areas are lined by pluripotent repair cells originating from the periodontium³⁸. In an animal experimental study, the regeneration time

after provoked root damage was within 18 weeks¹.

Intra-operative complications during the process can be interpreted as a "traumatic insertion" and can be controlled through a sensible, established technique and the application of well-designed mini-screw systems with associated accessories.

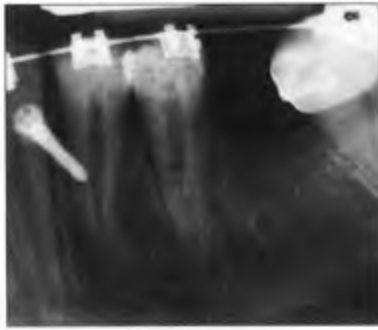


Fig. 6-6a Assessment of ortho-axial single tooth picture results in diagnosis of "hard tissue damage".

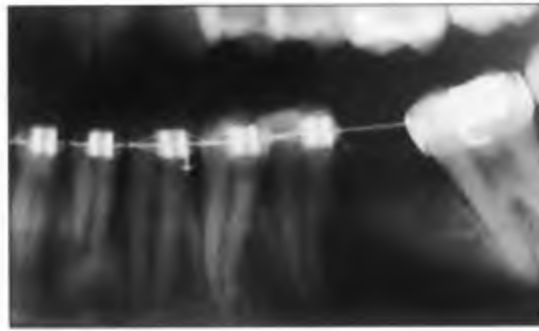


Fig. 6-6b Orthopantomogram (same patient) after removal of implant. The projection shows that hard tissue was not affected, as the exact position of the screw was within the periodontium.

Fig. 6-6 Interproximal insertion of mini-implant.

When pilot drilling, the revolutions per minute should not exceed 1500 rpm and should ideally be set at an optimum of 800 rpm with constant irrigation of sterile water or saline solution. Proper pre-drilling technique is continuous and in a straight line; constantly maintaining the same axis. High-speed drilling, insufficient cooling of the insertion area, intermittent movements or a change in the axis during drilling (widening the pilot hole) may all result in traumatic insertion and probably premature loss. This is due to reduced primary stability and compromised load-bearing properties of the implant subjected to orthodontic force⁵⁰.

6.3.3 Post-surgical Factors

The mini-screw inevitably penetrates the gingiva during insertion. The spectrum of incision techniques includes the direct insertion of the implant through the gingiva, tissue punch of the mucosa, or a mucosal flap. No specifics regarding the success rates or post-surgical complications of the different variations of soft tissue penetration have been verified.

Uneven wound edges and local bruises can develop with direct mini-screw insertion and could influence the healing process. As the screw threads progress through the tissue, a conveyance of basal cells into the depth of the osseous base is possible. Epithelial tissue has a tendency for quick proliferation. The osseous contact necessary for the retention of the mini-screw could possibly be interrupted as a result. Reports on the clinical impact are non-existent

at this time. Consequently, direct insertion of the mini-screw can be considered to be minimally invasive and biologically sound until proven otherwise.

Using a tissue or biopsy punch through gingival tissue produces a wound with smooth borders that quickly heals. Depending on the design, the mucosa can adapt to the transgingival portion of the mini-screw in the area of the perforation, sealing this area immediately. Mini-screws with a smooth collar may also reduce the danger of a peri-implant inflammation.

In some instances, a mucosal flap may be required to expose the underlying bone. Later, this surgical site may need to be closed with sutures. With this type of incision, there will be no primary adaptation or "seal" of the mucosa to the implant. The use of sutures could lead to other complications and post-surgical discomfort. When considering the small dimensions of the mini-screws, the advantages of the "flap" procedure do not appear to outweigh the disadvantages.

The choice between self-tapping and self-drilling systems will also affect the osseous surroundings. Self-tapping mini-screws require a pilot hole that corresponds to the length and diameter of the implant. Because the osseous volume to be displaced after pre-drilling is low, less tension will develop within the bone during mini-screw insertion. This generally creates very little post-surgical discomfort for the patient.

Self-drilling mini-screws are designed for placement without pre-drilling. Consequently, the amount of osseous material to be displaced is, therefore, relatively high. The implant design, the thickness of the cortical bone and the hardness of the bone set certain limits. Inserting

Fig. 6-7 Soft tissue implications.



Fig. 6-7a Mini-screw position in the region of muscle insertion. Patient discomfort indicates the employment of protection wax.

Fig. 6-7b Mechanical damage to gingiva by adjacent screw head.

Fig. 6-7c Ideal insertion position close to mucogingival junction.

self-drilling mini-screws requires more torque compared with self-tapping implants⁷³ but insertion techniques have proved to be successful. Inserting self-drilling mini-screws creates less bleeding and better fits the picture of orthodontic treatment regimen. Beside post-surgical discomfort, irritation of soft tissue (Fig. 6-7) is a possible side effect with self-drilling screws^{93,94}.

This is especially true when mini-screws are inserted apical to the mucogingival junction as the head may become embedded into the soft tissue. This can lead to painful irritation and a proliferative inflammatory response of the mucosa. The implant head often becomes inaccessible and uncomfortable to manipulate. Maintaining adequate hygiene around the mini-screw becomes more difficult. In the presence of a bacterial infection, perimucositis and subsequent peri-implantitis may cause premature loosening of the implant.

If mini-screws are placed within or proximal to frenum attachments, then mechanically provoked lesions can develop that may disturb speech, mastication, swallowing, or may be painful or increase the incidence of premature loss.

6.4 Application-related Factors

Application-related complications result primarily from a lack of experience of the operator. The results of mistakes in planning and execution could lead to intra-operative implant

fracture, reduced primary stability or loosening of the mini-screw during the active phase of treatment.

The risk of a material failure exists with placement and removal of the mini-screw. There is no defined yield point in clinical application of mini-screws. This is in contrast to simulation in homogeneous tests with standard lab parameters (e.g. constant speed and pressure during insertion). Spontaneous fractures are a result of clinical circumstances (bone quality and angle of insertion) and the insertion technique of the operator (constant applied torque, without variation in angle of force application). The yield point values among various mini-screws appear to be product-related and vary by 45%. Depending on the situation and operator, an identical implant will break at different torques⁷⁴. In a clinical study, *Motoyoshi et al*⁹² were able to show that insertion torques between 5 and 10 Ncm led to the lowest premature mini-screw losses. Higher or lower torques showed significantly higher failure rates.

If the implant is inserted up to its maximum length, further force application can result in fracture or in loss of stability. The implant loses its grip in the bone and spins, auguring the bone out of the hole. Fig. 6-8a illustrates the degree that torque increases when reaching the maximum insertion depth and also the decrease seen with mechanical overload and subsequent fracture or loosening of the implant. These data demonstrate the influence of individual insertion techniques. To avoid peak loads, it is important (Fig. 6-8b) to devel-

Fig. 6-8 Torque deviations with regard to inserted screw lengths.

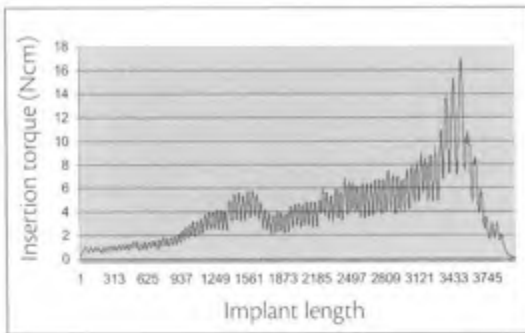


Fig. 6-8a Experienced operator: mechanical overload results in subsequent screw fracture; after insertion i.e. fully completed.

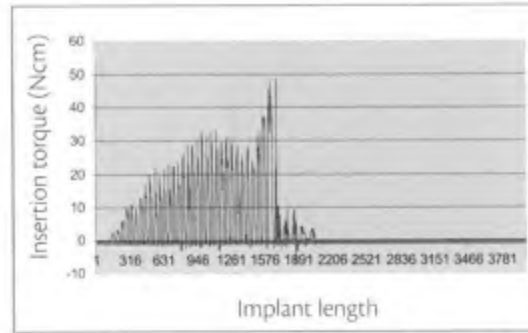


Fig. 6-8b Beginner: screw fracture; insertion not completed. Special emphasis must be given to the cumbersome movements with simultaneous high torque variations.

op a consistent insertion technique that features adequate and constant direct pressure on the mini-screw with smooth, slow rotation.

Experienced clinicians work with low and steady torque under smooth, continuous movements (Fig. 6-9a). They can perceive dynamic changes, like contact with adjacent structures (i.e. roots). The direction of the mechanical insult on proximal structures determines the extent of possible damage. With self-drilling systems and manual insertion, a perpendicular contact with a root can be clearly felt through an increased insertion torque and can, therefore, be corrected (Fig. 6-9b). If the implant hits the tooth tangentially, the torque barely increases up to the limit that can be detected by the tactile sense (Fig. 6-9c). Under unfavorable circumstances the torque change can be hardly perceptible and could lead to more damage to the root⁷⁴.

The advantages of a machine insertion (i.e. with a handpiece) lie in the transmission of a steady number of revolutions with constant torque. This method ensures an ideal mechanical load of the implant and offers reproducible basic conditions. Unfortunately, the loss of tactile "feeling" for implant and bone is disadvantageous.

Naturally, biomechanical aspects are also of decisive importance when choosing the insertion site. The insertion site is to be chosen with the intent that the desired dental movements can be carried out as completely as possible without having to move the mini-screw. The implant should not be in a position that would

interfere with tooth movement. Active orthodontic forces (e.g. springs or elastic chain) must be able to be easily connected to produce the desired effect. Beginners will likely experience some planning mistakes, but with increasing theoretical and practical experience, they will be minimized.

6.5 System-related Factors

At this time, comprehensive studies are in short supply. Primarily, our literature consists of case reports and technical descriptions^{23,24,28}. Case presentations often discuss spectacular solutions that illustrate the potential and the enormous versatility of cortical anchorage^{10,35,57}. The objectives of further scientific research for mini-screws should answer questions about healing period, improved methods of insertion, stability, force applications, and a spectrum of clinical applications.

Healing Method

In the literature, two philosophies are prevalent: immediate loading with orthodontic forces^{13,28,51} or permitting a healing period (of at least two weeks and longer)^{12,45}. Immediate loading shows a clear advantage for mini-screws over orthodontic implant anchorage that requires healing periods of two months up to one year⁶⁸. Immediate loading can positively affect the survival rate of mini-screws by increasing induction of osseous-active processes^{9,49}. In the course of ac-

Fig. 6-9 Insertion torque in relation to insertion depth.

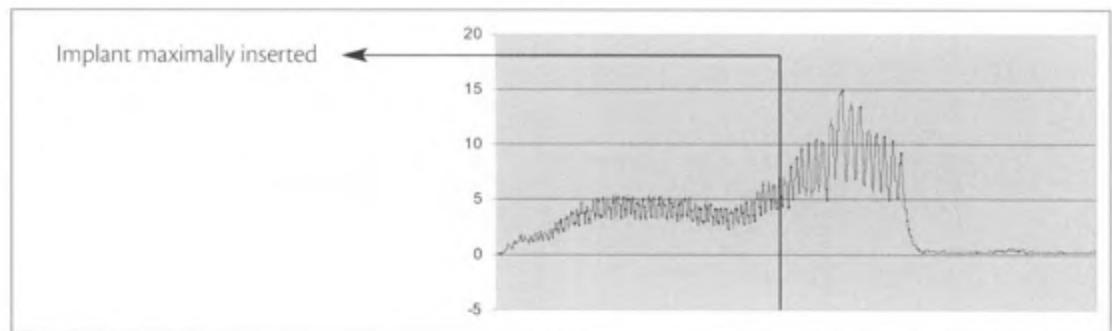


Fig. 6-9a Insertion torque in pure bone.

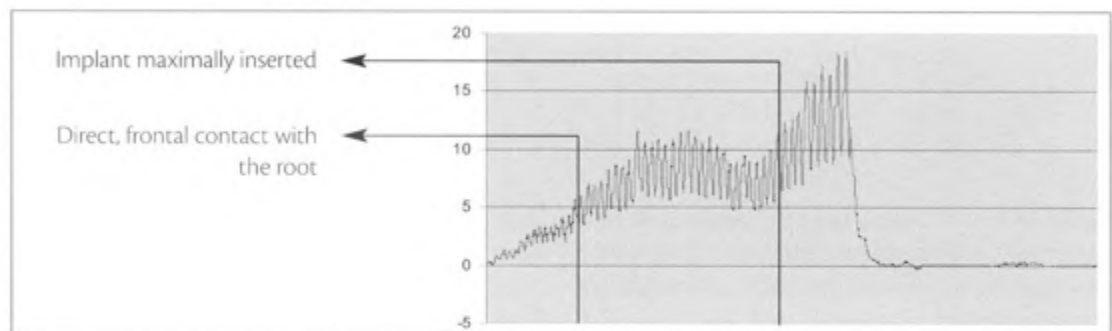


Fig. 6-9b Insertion torque during frontal contact with root of the tooth.

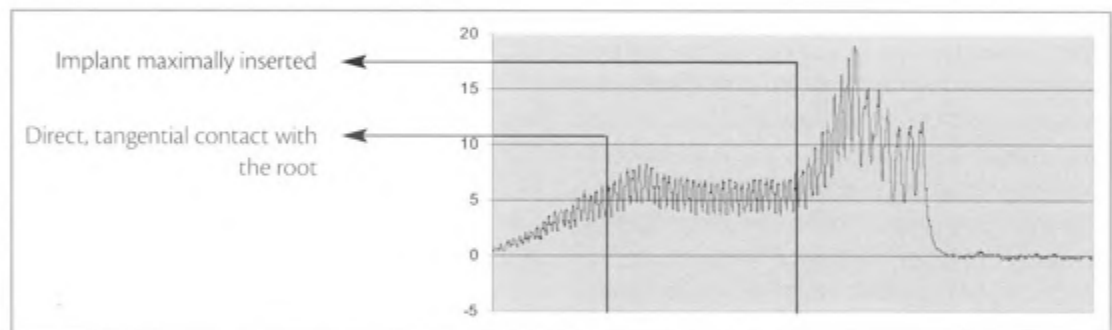


Fig. 6-9c Insertion torque during tangential contact with root of the tooth.

tive loading a certain degree of implant–bone contact is established. According to *Melsen and Costa*⁴⁹, between 10% and 58% can be reached. In the mandible the implants are surrounded by bone of greater density; in the maxilla there are wider-meshed trabecular structures. There is a more favorable relation of cortical to trabecular bone. A contact area of only 5% has been proposed to be able to withstand orthodontic forces¹⁶.

A waiting period of two weeks does permit gingival healing and some osseous regeneration by fibrous tissue. Secondary force application leads to formation of immature trabecular bone in which the implant can be mechan-

ically retained^{16,45}. However, it has also been observed, in some cases, that a change appears in granulation tissue with load application, in spite of a previous waiting period⁵⁵.

According to current research, the biomechanical utility of a mini-screw does not improve significantly by immediate loading or waiting for complete healing. In both cases, comparable success rates can be demonstrated^{14,56,61}.

Even with moderate loosening of a mini-screw, therapeutic measures can be mostly applied to the extent desired without an exchange of the implant becoming necessary⁴⁹.

Position Stability

From a clinical point of view, mini-screws maintain a stable position. *Liou et al*⁴⁵ have demonstrated slight changes in position during treatment. Therefore, a slight deviation under load cannot be ruled out, depending on the indication that the mini-screw is used for and also on the osseous structure. Changes in position often consist of a tipping movement in the direction of force application⁴⁵. Despite this tipping, experience has shown that mechanical retention in bone is sufficient and provides the necessary load stability^{55,56}. In this respect, *Liou et al* recommended a safe distance from anatomical structures, like roots, in very narrow areas. If mini-screws can tip, this may significantly limit the available insertion sites to be considered. Final data are currently not available in the literature to address these concerns. This can also be seen in the fact that there are still different opinions on the minimum amount of bone necessary for stable anchorage of mini-screws, with a range from 0.5 to 2 mm depending on the authors cited^{29,45,59}. All these investigations have shown clinical success. This permits indirect conclusions on the positional stability and perhaps necessary "safe zones" or distance from anatomical structures.

Force Application and Duration of Utilization

The forces applied to mini-screws^{13,28,45,51} vary from 30 to 500 g. It seems that appropriately applied forces have no influence on the success rate and the survival time.

The duration of utilization of mini-screws varies from 3 to more than 12 months⁵⁵. It seems that the duration of utilization is defined by attainment of the treatment goal rather than by failure of the implant.

Healing after Implant Removal

The removal of mini-screws is simple and can be achieved by de-rotation of the implant in the opposite direction of insertion, usually counter-clockwise. The implant is held securely by the insertion instrument and, therefore, cannot slip into the oral cavity. The healing of the wound occurs without any problems after the removal of the mini-screw. The lesion heals by epithelial regeneration within a short time (Fig. 6-10).



Fig. 6-10a to c Epithelial regeneration after removal of mini-implant.

Success Rates

Before success and failure rates can be discussed in detail, it is necessary to advise the reader that depending on the source, different definitions of success and failure apply. The most common definition of success is probably that the mini-screw remained in place until the treatment goal was achieved. The failure rate would, therefore, be the success rate subtracted from 100%. This definition will be used in the following paragraph.

The success rates of orthodontic mini-screws are interpreted differently in the international literature. Depending on the intra-oral location, the respective mode of load application and the product selected for insertion, the survival rates range from 0% to 100%^{5,24,52,55}. At the same time – as with many medical interventions – the result depends on individual circumstances and the abilities of the clinician (as already mentioned). The available studies all deal with very different initial circumstances and indications. However, the information regarding success can be interpreted as a general trend. If anatomically unfavorable regions are excluded, an effective success rate between 85% and 95% can be expected^{12,55}. Because mini-screws can be reinserted without great difficulty and at any time, then a 10% average probability of loss of one mini-screw seems quite acceptable. By strict case selection, favorable technique, and operator experience, success rates can be increased up to nearly 100%⁵⁵.

6.6 References

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Integration into Clinical Practice

In the preceding chapters, the choice of mini-implants, the steps for insertion, clinical applications as well as complications and risks were pointed out. This chapter takes up subjects that are to be considered when integrating mini-implants into your own practice (in addition to those already mentioned), regardless of whether the orthodontist places the mini-screw. The legal regulations or decrees specified here are valid in Germany and different laws and regulations may exist in other countries.

7.1 Conditions

The insertion of a mini-screw is an invasive procedure. After the proper indication for the use of a skeletal anchorage device has been determined, the patient must be informed in detail on benefits and risks of the entire treatment and, in particular, the surgical procedure. At the end of the consultation appointment

and before the actual insertion, informed consent must be obtained from the patient or their legal guardian.

On the basis of radiographs (Fig. 7-1) and models (Fig. 7-2), the position of insertion of the mini-screw and force application are planned. At the same time, an alternative location should be determined, if the planned insertion site turns out to be unsuitable. Whenever feasible, the head of the mini-screw should lie in the area of the attached gingiva and, depending on the mini-screw system, it should be suitable for the orthodontic mechanics planned (e.g. direct or indirect anchorage approaches). Unnecessary compensation bends and arch wire "artistics", as well as complicated anchorage mechanics, are avoided with careful pre-planning. This simplifies treatment and increases the patient's comfort. Developing a checklist (Table 7-1) makes treatment planning and subsequent insertion easier.



Fig. 7-1 Determining the mini-screw insertion site on the panoramic radiograph.



Fig. 7-2 Marking the mini-screw position on the cast.

Table 7-1 Checklist for the use of a mini-screw

Checklist: Use of a mini-screw
• Planning of the orthodontic treatment under consideration with the use of mini-screws • Patient education on the risks, benefits and alternatives of mini-screw placement • Patient education on the costs of the procedure • Creating the required records: panorex, plaster casts (model setup if necessary), photographs • Clinical planning of the insertion using the records: insertion site, angle of insertion, etc. • Marking the preferred insertion site on the model, radiograph and photograph • Mini-screw selection according to: insertion site, implant length and diameter, abutment design, loading of the screw, anticipated period of use • Mini-screw insertion • Coupling the mini-screw to the orthodontic appliance as planned • Removal of the mini-screw

Table 7-2 Equipment required for the insertion of orthodontic mini-screws

Equipment for mini-screw insertion
• Topical anesthetic or local anesthetic for infiltration anesthesia • Mini-screw (tray with mini-screw selection) • Explorer, mouth mirror, periodontal probe • Insertion instruments: ratchet/driver
For systems with pilot drilling (self-tapping mini-implants), additionally:
• Pilot drill • Implant handpiece or slow-speed contra-angle handpiece with torque reduction [800–1500 rpm], • Physiologic saline solution (sterile)

7.2 Practice Setting for the Insertion of Mini-screws

The application of mini-implants requires certain precautions regarding the practice setting or operatory set-up. Proper instruments and necessary devices, as well as the highest hygiene standards, must be guaranteed for these procedures.

The insertion of a mini-screw requires sufficient training for operator and staff along with experience in biological and biomechanical basics. The knowledge and experience of the team should be updated constantly by continuing education to ensure treatment meets the standard of care.

7.2.1 Devices and Instrumental Equipment

The insertion of mini-screws is a transgingival surgical procedure. The pins or screws have contact with saliva, mucosa, blood and alveolar bone. Surgical interventions under sterile conditions require, in addition to the suitable equipment (Table 7-2), surgical hand disinfection, sterile operation clothing, gloves, cover sheets, and instruments prepared according to hygiene guidelines.

For self-tapping mini-screws, pilot drilling is

required. For self-drilling mini-screws, pilot drilling *may be* necessary (see Chapters 3 and 4). During pilot drilling, cooling with sterile physiological saline solution (minimum 50 mL/min) is necessary. This can prevent thermal tissue damage that can result from heat development in the border region of bone. Handpieces are suitable for pilot drilling if they have a gear-reduction of 1:20 up to 1:100, at a maximum. Handpieces with a reduction of about 1:1000 are suitable for machine insertion and removal of mini-screws. The handpieces should be characterized by low vibration and smooth operation for optimal insertion. Handpieces that can be cleaned thoroughly without disassembly will simplify hygiene measures. After mini-screw insertion, a radiograph (periapical) can be taken, primarily for forensic reasons. This is especially true if more than topical anesthesia was used and patient feedback regarding root contact was unavailable. The shortcomings of radiographs to evaluate the outcome of mini-screw placement have been explained in the preceding chapter.

7.2.2 Hygiene Requirements and Legal Basis

The German Medical Products Legislation (MPG) regulates production, licensing, distribution, handling and reprocessing of medical products (MP). This applies to the safety, suitability and effectiveness of medical products, as well as health and necessary protection of patients and medical staff.

The decree concerning distributors of medical products (MPBetreibV; Part of the German Medical Products Legislation) contains essential regulations about maintenance, management and application of medical products. It also describes regulations regarding safety and measuring controls. According to §4, section 2 of this decree, the sterile, aseptic processing of medical products (such as non-sterile mini-screws and instruments) must be carried out with suitable validated methods of sterilization that are monitored and recorded. In Germany, recommendations for sterile processing or "requirements for processing of MP" are provided by the committee for hospital hygiene and infection prevention of the Robert Koch Institute (RKI). If the dentist or orthodontist should choose to disregard these recommendations, he must be able to prove that his hygiene precautions for all procedures have the same level of quality as if these hygiene standards were a basis for those actions. In other countries, the regional regulations are to be followed.

The hygiene guide for dental practice was drafted by the German Working Group for Hygiene in Dental Practice (DAHZ) and consists of a written summary of how to develop an individual hygiene plan. A risk assessment of the medical products that are used in the practice should be completed.

Initial and repeated use of medical products (handpieces, implant drivers, pilot drills, etc.) assumes in general that the manufacturer provides information on their appropriate processing. In addition, these medical products are classified before processing with the help of a risk assessment as uncritical, semi-critical or critical (Table 7-3).

Design- and material-specific details of the medical products being used can increase demands for hygienic processing. Semi-critical and critical medical products are further subdivided into medical products that do not have special requirements (group A) or those with increased requirements (group B). Medical products that increase demands for processing include those in which:

- the effectiveness of cleaning cannot be assessed immediately by inspection (e.g. due to a long cavity with only one opening, in particular those with a narrow lumen at the end, and complex, poorly accessible surfaces that are therefore difficult to rinse and clean).
- effects from processing or transport may

Table 7-3 Assessment and categorization according to the Medical Products Groups by the German Committee for Hygiene in the Dental Office (DAHZ)

Uncritical medical products: Medical products that contact the intact skin exclusively
Semicritical medical products: Medical products that contact mucosal surfaces or pathologically altered skin
Critical medical products: Medical products for use with blood, blood products and other sterile pharmaceuticals; medical products that pierce the skin and thereby contact blood, internal tissues or organs, including wounds

influence the application or functional safety (e.g. surfaces sensitive to flexion). They demand a higher expenditure in technical-functional checks.

- the number of applications or the processing cycles are limited to a certain number by the manufacturer.

After machine or manual processing (i.e. disinfection and cleaning), instruments in critical group B (surgical treatment) will be packed and sterilized in a steam sterilizer (cycle B, if necessary S). Hollow bodies (e.g. handpieces) can be safely processed only by sterilizers (cycle B; fractionated pre-vacuum) and sterilizers of the cycle S type with presentation of a suitable manufacturer's certificate (detailed performance spectrum).

According to the German Institute for Standardization 13060, steam sterilizers are divided into three different types (N, S and B):

- Type N: autoclave, steam gravitation procedure: suitable for firm, massive MP in unpacked state.
- Type S: autoclave, steam injection procedure: written confirmation of performance spectrum by manufacturers necessary.
- Type B: autoclave, fractionated pre-vacuum: for all hollow and porous MP in packed state.

In cooperation with the federal dentists chamber (Bundeszahnärztekammer), the current hygiene plan for dental practices was created. Generally, thermal methods are preferred for processing medical products in cleaning and disinfection units. However, manual procedures are also permitted.

Only personnel with the proper education and experience may be in charge of the upkeep (maintenance, inspection, repair and processing) of medical equipment. A documented release for use and storage has to occur in each case after processing. Only detailed documentation, according to a standardized protocol, can serve as evidence for an orderly, completed process to satisfy any potential forensic inquiry. Changing working conditions, introduction of new procedures or new medical products require a continuous update of knowledge and instruction.

7.2.3 Hygiene Conditions with Mini-screws

The insertion instruments for mini-screws are rated as critical medical products as they are used for invasive procedures. Cross-slot and "inside edge" implant drivers for manual insertion of mini-screws are classified as a "critical medical product, group A". Transmission instruments with cavities and only one opening (ratchet systems, implant driver blades with external polyhedron) or systems for pilot drilling (contra-angle handpiece) are classified as "critical medical product, group B".

To comply with the required hygiene standards, a steam sterilizer (autoclave) of class S/B is required for mini-screws. After mechanical or machine disinfection and cleaning, according to the manufacturer's instructions, non-sterile mini-implants, insertion instruments and trays (e.g. plastic bags, transparent sterilization pack with a sealing seam width of 8 mm, containers, dental cassettes) must be sterilized by trained staff. Furthermore, the date of sterilization must be documented on the pack and be checked prior to use. Sterile mini-screws, as well as the surgical set of instruments for the insertion, must be stored in clean and dry surroundings in cupboards or drawers. If there is moist internal packaging, damage or unintentional opening of the sterile pack, the mini-screw and associated instruments should not be used.

According to RKI guidelines, the maximum storage deadline for container packaging or transparent packs of sterile goods is 6 months after steam sterilization. Mini-screws delivered in sterile packaging (e.g. gamma-sterile unopened blisters) may be used up to 5 years after sterilization. The corresponding information on the label should provide a sterilization expiry

date (see Chapter 3, Fig. 3-32). When the mini-screw is unpacked, it has to be compared to the description on the pack (size and type) for confirmation. Nothing should touch the implant's surface as it may damage the mini-screw.

Sterile and non-sterile mini-screws are both commercially available. Pre-packaged sterile mini-screws are aseptic, have no particles, cytotoxic substances (e.g. endotoxins) and microorganisms on the implant surface. This substantially reduces the risk of infection when the device is inserted. Sterile mini-screws simplify insertion by reducing the number of steps that may be at risk for surface contamination. Non-sterile mini-screws require more pre-surgical preparation time (see also section 3.5.1). Systems that require pilot drilling increase the duration of the procedure. Accidental contamination of the mini-screw or instruments (especially the pilot drills) must be avoided during the insertion procedures.

A disregard of the basic hygiene rules (i.e. sterile work field, "pre-operative mouthwash", etc.), aseptic regulations for invasive procedures, and also an inadequately trained staff can lead to failures and forensic consequences. Every instrument in a mini-screw system should only be used for its specific application and after use it is placed in physiological saline solution to prevent drying of surgical remains (blood, saliva, tissue residuals). The instruments are then prepared for disinfection and cleaning. Instruments with dull cutting edges should be sorted out and be replaced immediately. The disinfectants for pilot drills and cleaning agents for rotary instruments should be exchanged prior to a maximum of 20 applications. The concentration of the disinfection solution and time the instruments are in the solution are to be followed according to the instructions of the respective manufacturer. Ideally, cleaning of the instruments should occur in an ultrasound bath at room temperature and without the instruments touching each other. It is easier to clean and maintain instruments that are readily dismantled. Rinsing hollow implant handpieces with distilled water, helps to prevent clogging of the irrigation system by precipitated sodium chloride crystals. In general, disinfectants and cleaning agents are to be rinsed off very thoroughly with water and the instruments dried carefully (e.g. by flow of air). The instruments should never lie or be stored in a humid or wet environment for any extended

Table 7-4 Risk factors associated to mini-implant insertion

- Reduced blood coagulation, for example, due to anticoagulant therapy or congenital or acquired blood coagulopathies
- Reduced wound healing or bone regeneration, for example, in case of uncontrolled diabetes mellitus, tobacco or alcohol abuse, metabolic diseases with impact on wound healing or bone regeneration
- Immune suppressive therapy such as chemo- or radiotherapy
- Infections or inflammations of the oral cavity such as gingivitis or periodontitis
- Untreated parafunctions such as bruxism
- Insufficient oral hygiene
- Lack of compliance
- Reduction in bone quality or quantity, soft tissue recession

time. The integrity of all instruments should also be checked. Afterwards, all instruments are placed back into the system's trays or cassettes and are then sterilized. Detailed information on instrument care should be evident from the documents supplied by the manufacturer. Unfortunately, there are considerable differences in quality and quantity of these directions among suppliers.

7.3 Documentation of the Procedure

The insertion of mini-screws can be graded as a surgical process with possible complications, risks and possible delayed after effects. Therefore, it is imperative to provide proper documentation of the procedure so that each step of the procedure can be reconstructed from the description. In addition, flawless archiving of the reference number and charge number of each inserted mini-screw is important so that it may be traced in the case of complications. Specially designed self-adhesive labels are often delivered with mini-screws (see Chapter 3, Fig. 3-32) and make this documentation much easier. The labels are simply applied to the patient's chart. For reasons of forensic safety, the protocol and steps of the insertion and any complications that occurred during the process are to be recorded as well^{4,7,8}.

The use of cortically anchored mini-screws in orthodontics is still a relatively new treatment mode. As such, one is legally expected to exercise caution and extreme diligence in regard to integration into treatment. Special attention needs to be directed towards indication, patient education, informed consent, surgical intervention and post-surgical follow up⁶.

The terms and conditions of malpractice insurance should be reviewed carefully with regard to medical risks covered. If surgical interventions or implant placement, including mini-screws, is not included, specific coverage must be requested⁵. Continuing education and advanced training of the clinician in the form of workshops, seminars or the detailed study of online or CD-ROM instructional videos are necessary to maintain up-to-date treatment methods and ensure state-of-the-art patient care.

7.4 Patient and Mini-screws

The use of mini-screws needs careful evaluation of the indications. The devices should only be used with motivated and co-operative patients exhibiting good oral hygiene. To determine indications or contraindications, a general anamnesis (medical history) of the current physical condition is required (Table 7-4). When selecting patients for this procedure, the general contraindications for dental/surgical interventions are to be considered. Among others, these would include: serious general diseases, drug therapy, and a potentially negative impact on the general disease or health status. A consultation with a specialist can help identify risk factors.

Contraindications, specific to the oral environment, include oral hygiene (Fig. 7-3), poor patient compliance, existing habits (e.g. tongue thrusting, parafunctional habits), smoking, or smokeless tobacco, as these can contribute to a premature loss of implants. Therefore, it is important that a health history form is filled out and informed consent is given and documented prior to mini-screw insertion (see Appendix 7.7).

Table 7-5 Recommended content for informed consent (examples)

Informed consent: recommended content for the insertion and clinical use of mini-screws (examples)	
Risks, benefits and alternatives of treatment with mini-screws	
Exact course of the pre-surgical, surgical and post-surgical phase	
Potential complications and general risks • Risk of infection • Pathological influences – bacteria (endotoxins) – inflammation – epithelial cells – mucositis – periimplantitis • Mini-implant failure	
Lack of compliance • Oral hygiene, smoking • Parafunctions (tongue pressure, habits)	
Individual, case specific risks • Damage to the roots • Insufficient bone support • Insertion in the attached gingiva/mucosa • Insertion in the proximity of frenula • Insertion in the proximity of deciduous teeth and tooth follicles • Insertion in the proximity of roots • Insertion in the proximity of fresh extraction wounds • Insertion in the proximity of sinuses and the floor of the nose • Insertion in the proximity of blood vessels and nerves • Bruises	
Explanation and evaluation of treatment alternatives • Headgear, lip bumper • Extraction • Interproximal reduction, etc.	
Costs (written quotation) • Explanation of the costs and comparison with the costs of the treatment alternatives (at the end of the consultation)	
Written informant consent • Signed – at free will of the patient • 24 hours consideration time recommended • Signature of the legal guardian(s) if necessary • Offer continuous support and demonstrate willingness to answer questions at any time • Hand out a (carbon-) copy of the signed written informed consent to the patient	
Side effects:	
As side effects of surgical procedures the following may occur: • Temporarily localized swelling, edema, hematoma • Temporarily altered sensations • Temporarily restricted masticatory function	



Fig. 7-3 Lack of proper oral hygiene (demonstrated by disclosing solution) after bilateral mini-implant insertion in the maxillary anterior region.

7.5 Patient Education and Approval

A doctor–patient relation based on trust includes a regular update on the progress of treatment for the patient. The individual phases of treatment should be explained. Educating the patient thoroughly on what can be expected helps them lose their fear of the procedure⁹.

Before the insertion of mini-screws, the operator must inform the patient about when the insertion is planned, what to expect, what the consequences and potential risks are, and what the costs of the intervention will be (Table 7-5). This information has to be given well in advance, in an individual manner, and it must be documented¹. A signature from the doctor, patient and the dental assistant as a witness are recommended. General information, provided only in handouts or forms, is unacceptable^{10,11}. Individual, case-specific risks or unfavorable structural conditions can be explained and made more understandable by using a panoramic radiograph with drawings on a tracing acetate placed over the film. These diagrams can be marked individually, and assist in patient education and documentation.

Only after complete patient education and written, informed consent of the patient (see Appendix 7.7) may the treatment be initiated¹. If the patient is a minor, then the presentation of the treatment plan and the written consent of the legal guardians must be documented².

The advent of mini-screws in orthodontic treatment requires careful planning, safety and sterilization, and excellent communication with patients. Proper planning of all aspects will help to minimize risks, avoid surprises, and increase the potential for success in treatment.

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Consent Form for the Insertion of One or More Mini-Screws During the Course of Orthodontic Treatment of:

Name of patient: _____

Name of treating doctor: _____

1. Information regarding the procedure

Course of procedure:

- Topical anesthesia
- Infiltration anesthesia
- Tissue punch at the insertion site
- Pilot drill
- Insertion of ____ (number) mini-implants
- Coupling of the mini-implant to the orthodontic appliance
- Removal of the mini-implant (at the conclusion of treatment)

Mini-screw system: _____

The potential risks and complications of the planned procedure and the resulting treatment have been discussed in depth, especially the possibility of:

General Side Effects/Complications:

After the procedure, pain may persist. Generally, it will wear off within a few hours after the procedure. Bleeding or prolonged hemorrhaging are very rare but can occur, especially in patients with hemorrhagic diatheses. Existing allergies or sensitivity (for example, from the anesthetic, disinfectant, latex) may lead to transient swelling, itching, sneezing, skin rash, dizziness or other related reactions. Severe complications affecting vital functions (heart, circulation, respiration, kidneys) or permanent damage (for example, organ failure or paralysis) are extremely rare.

Specific Side Effects/Complications:

- Root damage due to proximity of the mini-screws
- Soft tissue injury during placement
- Fracture, loosening or premature loss of the mini-screw
- Inflammation of the soft and hard tissues surrounding the mini-screw
- Individual risks:
- _____
- _____

Post-operative Care Instructions:

- For 24 hours after the procedure, please refrain from smoking, drinking alcohol or exercising
- Do not eat while the area is still numb
- It is very important to include the area surrounding the mini-screw into your daily oral hygiene routine according to the instructions received from your doctor. In the first days following the insertion, the application of a disinfecting agent (mouth rinse) may be required. Regular recall appointments will be necessary as part of the post-operative care.
- Please immediately contact your doctor if you experience one of the following symptoms: continuous hemorrhaging, severe swelling, throbbing pain or other later discomfort at the insertion site.

2. Consent

I was informed that the above procedures will be performed on me. The reason and the different steps involved have been explained to me. The risks, benefits and alternatives were discussed. I am aware that new information may be obtained during the procedure which may necessitate other, not previously discussed measures. Possible physical, psychological and professional complications after the procedure have been pointed out to me.

All my questions have been answered. I was sufficiently educated regarding the details of the above procedure and any further clarification is not necessary. I understand that I can revoke my consent at any time.

I confirm that I have listed all the ailments that I am aware of in the health history.

Additions:

My decision is well thought through and I require no further time or information to reach a decision.

- ☐ **I hereby consent** to the insertion of mini-screws. I agree to the anesthesia and potentially necessary changes from the anticipated course of action as outlined above.

If you refuse certain steps of treatment, please specify below:

- ☐ **I do not consent** to the proposed treatment. I was informed of the consequences this decision may have.

(City)

(Date)

Patient*

Doctor

Witness

* Parent/Guardian for minors

Outlook: The Shape of Things to Come

Assigned the task of composing the last chapter of this book, the authors were challenged to provide an outlook for orthodontics or, in effect, predict the future of mini-implant anchorage. Baseball legend Yogi Berra's words immediately came to mind: "It's hard to make predictions, especially about the future." However, when considering over a century of orthodontics that stretches behind us, perhaps German poet Johann Wolfgang von Goethe's comments are more compelling: "I find the great thing in this world is, not so much where we stand, as in what direction we are moving." It certainly appears that the introduction of mini-screw anchorage is rapidly changing the face of orthodontics.

"Scientific planning" – the great panacea of the 1930s – was based on faith in the ability of reason and science to overcome nearly any problem. The same faith can be seen in today's orthodontist, especially considering the growing emphasis on evidence-based care. In the 1936 film version of H.G. Wells' *The Shape of Things to Come* (a cautionary tale, predicting the future), a child, listening to her grandfather's history lesson, happily expounds, "Keep on inventing things and making life lovelier and lovelier." That is the ambition of those of us who have started inserting tiny screws into willing patient's jaws. The advent of improved anchorage from mini-screws should empower us to re-examine all aspects of orthodontic problem-solving and look for possible improvements to facilitate treatment for the public.

8.1 A Spike in the Ice: a Real Paradigm Shift

Our readers are standing at the cusp of a *real* paradigm shift in our specialty; one that has a sound theoretical basis and that will reinvigorate an emphasis on orthodontic diagnosis, will produce sweeping and substantial changes in orthodontic treatment planning and biomechanics, and will likely result in improved effectiveness and efficiency of Edward H. Angle's beloved tooth regulation.

In the recent past, some in the orthodontic industry have made comments such as "Orthodontists will never get involved in placing screws in patient's jaws and they will even be reluctant to refer patients for these invasive services." Although this assessment was spot-on for orthodontists at the turn of the 21st Century, the situation has changed rapidly⁵⁵. The advantages and benefits of having temporary and predictable anchorage seem to outweigh any perceived risk or disadvantages for patients or practitioners. It now appears obvious to many that the addition of mini-screw anchorage to the orthodontic armamentarium will soon be as commonplace as headgear and elastics are to us now.

8.1.1 An Orthodontic Tug of War

Throughout the history of orthodontics, we have concentrated our efforts at planning where we wish to move teeth and then attempting to design mechanisms that would permit us to predictably produce the desired results. Unfortunately, anchorage control, or more specifically, predictable tooth movement, has been problematic. As an analogy, we might consider a "tug of war" taking place between two

groups of people on a sheet of ice. Unfortunately, there is little predictability to the results as both teams of workers will likely be slipping and sliding around on the skating rink.

Orthodontists have created elaborate constructs (replete with often onerous requirements on patient compliance) to prevent the movement of some groups of teeth in deference to others. Some examples included: pitting groups of teeth, tied together in some fashion (e.g. segmental arches, transpalatal arch, lingual arch, Nance arch), against other teeth; tipping teeth to increase resistance to movement (e.g. "tip-back" bends or "preparing anchorage"); or even the addition of elastics, headgears, and functional appliances.

Let's return to our skating rink analogy. If we tie a rope around several members of one team on the ice and then ask them to lean back against the rope, it may again make little difference to the results of this unpredictable tug of war. If, however, we were to drive a steel pole into the ice (a "spike in the ice") and one team was permitted to brace themselves against it, the situation suddenly changes (and this team is more likely to quickly and predictably win the contest). That is the specific intent of incorporating mini-screw anchorage (another type of "spike in the ice") into orthodontic biomechanics.

8.1.2 Primer, Preparation and Performance

Before embarking upon any journey, it is often advisable to consult a roadmap or at least stop at the nearest petrol station for directions. Unfortunately, this type of preparation is alien to many folks' nature; they would rather set off on an adventure and discover new horizons on their own. Without those brave souls, such as *Creekmore* and *Eklund*²³, we would still be arguing about the most efficient method of canine retraction or the most effective technique for preparing anchorage rather than the present discussion of mini-screw based anchorage.

More can be learned from one teacher than from two books. German proverb

A primer is an introductory textbook and, as such, our gentle readers have now been exposed to substantial background material on mini-screw design, selection, and usage. How-

ever, no single textbook should be considered the quintessential handbook for incorporating this technology into practice. As Alexander Pope cautioned, "A little learning is a dangerous thing." In this respect, more than one source of information should be consulted prior to involving "live" patients.

One learns by doing a thing; for although you think you know it, you have no certainty until you try. Sophocles

There should be more to this learning process than the typical "minimum clinical experience" (i.e. "see one, do one, teach one, have one").

Certainly, after sufficient educational due diligence and also adequate preparation and planning (there is no substitute for seeing the insertion process in-person, especially for assisting staff members), then inserting a mini-screw under supervision and perhaps even having one placed in your own mouth would be valuable experiences. Don't be the first to jump on the bandwagon, but also don't be last in the parade either. Confidence, expertise, and increasing rate of success with mini-screws will only come with clinical experience. So it is time to get started.

8.1.3 Doing the Due Diligence

What we hope to do with ease, we must learn first to do with diligence. Samuel Johnson

Although the simplified distillation of the mini-screw technique could be considered mundane (driving in a wood screw with a screwdriver), there is obviously more to it when that screw is being inserted into a patient. Prior to the insertion of your first mini-screw, an appropriate level of due diligence is certainly required:

- 1) Education of clinician, staff, and referral network
- 2) Selecting an appropriate mini-screw system
- 3) Acquiring the necessary armamentarium
- 4) Treatment planning of TAD-supported mechanics
- 5) Patient education and informed consent
- 6) Preparation of patient and clinical procedures
- 7) Implant insertion
- 8) Application of biomechanics
- 9) Post-operative follow-up

Although our specialty is rapidly benefiting from many articles describing temporary anchorage devices (TADs) and innumerable continuing education courses, the majority of these offerings consist of anecdotal case reports or are proprietary in nature. Therefore, we should be cautiously optimistic that a new emphasis on orthodontic research involving mini-screws will also increase as quickly as our adoption of this technology in practice. The cooperation of "town-and-gown" is critical to safely and effectively advancing this new "golden age" of orthodontic mechanics.

8.1.4 Multitudes of Systems: The Paradox of Choice

It seems that nearly every orthodontic manufacturer has offered up some type of mini-screw and new ones seem to spring up every month. There are so many screw head designs, shaft diameters and lengths now available, the practitioner's decision process can become paralyzed⁷⁹. How do you decide what to purchase and use?

The clinician must first decide what kind of clinical applications will benefit from the introduction of mini-screws in their practice. For instance, only a very basic type of mini-screw (e.g. Imtec, MTAC, and Vector) is required for most direct anchorage applications (i.e. simple attachment of elastic forces directly to the TAD). On the other hand, if indirect anchorage mechanisms will be used, such as placing sectional wires from the mini-screw to stabilize teeth that are used as anchorage units, then mini-screw designs with some type of slot, cross slot, or tube would be preferred. It would seem then that a mini-screw head design that can be easily adapted to either alternative would be preferable. Mini-screws with a multifunctional head are Ortho Easy® (Forestadent) and tomas®-pin (Dentaurum).

If the recommendations from the previous chapters are distilled, it appears that a selection of 6, 8 and 10 mm self-drilling mini-screws would simplify inventory and also satisfy the majority of probable clinical uses. In addition, the use of a tissue punch or pre-drilling a pilot hole may also be required if a mini-screw must be placed apical to the mucogingival junction or in dense bone. Since the actual thickness or density of alveolar bone is only determined once self-drilling of the mini-screw insertion is initiated

(obviously, a trifle later than you'd prefer to have known; unless Hounsfield Units or cortical bone thickness are measured from a CBCT), it may be prudent either to drill a pilot-hole or at least a starting "pit" or "divot" purchase point, even when using a self-drilling mini-screw⁸⁰. Pilot-hole drilling would seem most advisable when inserting screws in the often-dense bone of the mandible, especially for adult males. Finally, topical anesthetics, like TAC 20% Alternate (Universal Arts Pharmacy, Hialeah, FL, USA; Professional Arts Pharmacy, Lafayette, LA, USA), EMLA (AstraZeneca, Wilmington, DE, USA), DepBlu (Steven's Pharmacy, Costa Mesa, CA, USA), or Oraqix (Dentsply Prof., York, PA, USA), are probably sufficient for placing mini-screws in most patients; however, you should always be prepared to provide a simple "spot" infiltration of a typical dental anesthetic for any patient experiencing discomfort⁸¹.

8.1.5 Education and Informed Consent

Until the use of mini-screws becomes more routine and commonplace in contemporary orthodontics, most patients are going to be initially uncomfortable with the concept of "implants" for orthodontics, no matter how small they appear to be. At first glance, the idea seems to be a bit extreme and unnecessarily invasive to them. However, it does seem rather curious that a patient may balk at the idea of having a mini-screw inserted yet readily consent to having extractions, frenectomies, gingival grafts, or even orthognathic surgery. It is simply a matter of "familiarity", adequate patient education and reviewing the risks and benefits of treatment alternatives. If this is approached compassionately, concisely, and consistently, informed consent will be an easy process for patients and practitioners. As more patients benefit from mini-screw enhanced treatments, then they will "spread the word"; much as today's prospective orthodontic patient now basically knows what to expect with "rubber bands, headgears, or brackets and wires".

8.1.5.1 Consulting with the Patient

A simple discussion of the biomechanical advantages of mini-screws compared to the inherent risks, along with a description of the basic procedures required for placement, should

Fig. 8-1a and b A basic demonstration typodont with a single mini-screw (tomas'-demonstration model, (a)) is less imposing to patients than typodonts "filled" with mini-screws, auxiliaries, and braces (b).



allay patient fears and permit them to provide informed consent for the procedure. The majority of patients will rapidly realize the advantage of predictable and effective directional forces compared to the associated costs (i.e. some discomfort and possible risks). Both *Kravitz and Kusnoto*⁴⁹ and *Graham and Cope*⁴⁰ have provided excellent summaries of the risks and complications for orthodontic mini-screws.

Patient discussions would also benefit from a copy of a published report or photographs of another patient with similar treatment circumstances⁴¹. However, showing patients 8" x 10" enlargements of mini-screws or exposing them to typodonts that are filled like "pin-cushions" with mini-screws can be very intimidating. A simple and unimposing alternative is the *tomas'-demonstration model*, a clear quadrant typodont with only one "pin" in place (*tomas'-demonstration model REF 302-006-000, Denta-urum; Fig. 8-1a*).

8.1.5.2 Informed Consent

It is important for patients and the practice to have a copy of a signed form securing informed consent (see the IC form available from the American Association of Orthodontists as it includes a basic description of risks and limitations with TADs)⁵. The patient discussion should include the possibility of premature loss and replacement, resolution of any inflammation or infection, potential for iatrogenic ankylosis, "nicked" roots, consequences of screw breakage – not an unlikely event (decision: leave the broken portion⁴¹ or surgical trephination), damaged nerves or roots, or perforation of the maxillary sinus. Complications or allergic reactions from any anesthetics that may be utilized must

also be a consideration. Finally, a combined pre- and post-operative instruction sheet (Fig. 8-2) can be prepared for patient and parental reference. This document might also include the rationale for selection of TAD-support and the basic procedures that will be performed.

In the current litigious environment, practitioners must confirm that their malpractice insurance policy covers the procedures involved in the use of TADs. For example, insurance from the American Association of Orthodontists Insurance Company (AAOIC)⁴ describes the following limits of liability exclusion: "This insurance does not apply: 1. To any injury resulting from the performance of any surgical procedure or surgical extraction or the performance of a non-surgical extraction. This exclusion does not apply to: 5. The placement of micro implants that do not involve the reflection of a surgical flap."

8.1.5.3 Adolescents: Special Considerations

The majority of patients seeking orthodontic treatment are adolescents. This begs the question, "Can mini-screws be used reliably for this patient population?" *Anka*⁷ has cautioned that the "cortical bone will not support a mini-screw for patients under the age of 15" and that treatment should perhaps be delayed until the second molars have fully erupted or else screws should be employed only if "limited tooth movement [is] undertaken". In this regard, *Garfinkle*³² reported 80.5% success for mini-screws for a sample of 13 adolescents (average age 14 years, 10 months). Although the bone turnover rate is higher and bone density or cortical thickness may be somewhat less, it certainly appears that TAD anchorage may permit for

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ORTHODONTIC ANCHORAGE DEVICES - MINI-IMPLANTS OR TADS

Mini-implants or temporary anchorage devices (TADs) are simple, small screws that are placed in the jaws to facilitate tooth movements during orthodontics. Often this tooth movement occurs in a manner that could not be accomplished with only traditional orthodontic mechanisms, or would require alternative treatments (headgear, extractions, surgery, etc.), and longer, more complex treatment mechanics. The placement of a mini-implant is a brief, minimally-invasive process that has three parts: anesthesia, placement, and attachment of orthodontic forces. Patients have reported minimal discomfort or problems with mini-implants, but their orthodontic treatments and results have been significantly enhanced; making TADs exceptionally helpful little tools.

PRE-OPERATIVE INSTRUCTIONS

To prepare for mini-implant (TAD) placement, we recommend that you take an over-the-counter analgesic (e.g., Ibuprofen or Motrin) about an hour prior to your appointment.

We use a very strong topical anesthetic called TAC gel. This material is simply swabbed with a cotton tip onto your gum tissue just in the location where your mini-implant will be placed. This gel will provide numbness to your gum tissue in about 5 minutes and lasts about 30 minutes. Remember, the mini-screw is very small, so the area to be numb does not have to be very large either (it is not like having a dental filling or extraction of a tooth).

In some situations, we may also place a drop of anesthetic, just under the gum tissue, with a typical dental syringe and then the mini-screw will be placed into that same exact spot.

We will swab the gum tissue with a disinfecting material before the sterile mini-implant is inserted. The entire process of actually placing each mini-screw typically takes about 2-3 minutes. During placement, you will feel pressure from the implant, but no pain is expected.

POST-OPERATIVE INSTRUCTIONS

We recommend that you take Ibuprofen, as needed, for any discomfort.

Please rinse with a capful of Peridex (Chlorhexidine Gluconate) for 30 seconds, specifically in the area of the mini-implants, twice each day for one week. If you notice any gum-tissue swelling around the mini-screw, you may continue to rinse once each day to help reduce it.

You must keep the mini-implant clean to avoid failure or loosening of the device. A soft bristle toothbrush can be dipped into a capful of Peridex to massage debris, food, and plaque away from the mini-implant along with regular oral hygiene.

Avoid hard, chewy, or sticky foods around the implant. The same list of foods to avoid with braces is applicable for mini-implants.

Fig. 8-2 TAD instruction sheet for pre- and post-operative reference.

some modicum of success in the adolescent. However, a greater risk of loss would be expected in a younger population of patients and this must be conveyed to prospective patients and their parents.

Caruso²¹ recently described the average screw failure rate for orthodontic residents (Loma Linda University) at about 14% compared to the 8–30% loss reported in our scientific literature. The chance of loss and the resolution of this issue must be discussed with the patient prior to initiating their use. So patients must be cautioned, “we win most of the time, but lose a few”. If we have a “loose screw” or completely lose one, then we will likely need to replace it in order to continue our mechanics. Although we also have broken brackets, wires, and appliances during orthodontic treatment, a lost screw is a bit more disconcerting for patient and practitioner.

8.2 Innovations on the Horizon – The Future is Now

Recent orthodontic publications and symposia have featured an exponentially increasing number of reports on innovative concepts, biomechanics, appliances, and auxiliaries that utilize mini-screw anchorage. Although mini-screws should not be chosen for all patients (remember that conventional orthodontic mechanics have served us well for over a century), sensible application of temporary skeletal anchorage will quickly find a substantial niche within everyday clinical practice. Although incorporating mini-screws into orthodontic mechanics will alter the treatment planning process, it will not change diagnosis – still the hallmark of our specialty. The most common malocclusions that confront the specialist are those with arch length discrepancies and Class II malocclusions. It seems that mini-screws can play a significant role in the correction of both and, as a result, contemporary biomechanics may be enhanced or dramatically changed forever.

8.2.1 The Changing Face of Orthodontics: Altering the Extraction Decision with Mini-screws

The most divisive and persistent argument throughout the history of orthodontics has been whether or not to extract teeth^{5,17}. For patients who present with some degree of crowding and/or protrusion, the question is not whether to extract, but when and which teeth (even if only third molars)? The instability of expansive treatments to avoid extraction has been repeatedly examined and reaffirmed^{53,61}, yet we continue to (re-)introduce “new” ways of squeezing all teeth into dental arches, encroaching upon the enveloping muscular equilibrium, and “filling” the face and smiles with teeth to over-flowing. All this, in the hopes of avoiding the extraction of premolars, often insures the removal of third molars and the utilization of “permanent” retention, *permanently*.

Expanding younger (with jackscrew appliances) or older (with self-ligating brackets and expanded arch wires) patients does not ensure better stability or esthetics (smiles or profile). The hype is new but the patient’s biology has not changed.

8.2.2 Full Face Orthodontics?

Many profess that some type of expansion (early or late; active or passive; with “special” braces or fixed/removable appliances) is required for the correction of nearly all malocclusions. This has followed hand-in-hand with the unsubstantiated dogma that only treatments conducted without the extraction of succedaneous teeth will result in “full faces, square jaws, voluptuous lips, and wide smiles”^{25,379}. Taken a step further, the implication is that expansive non-extraction treatments produce bimaxillary protrusions that produce the best faces over time (with aging) and that these results are specifically desired by the public.

Interestingly enough, today’s esthetic icons may reveal “full lips” but bimaxillary protrusions and lip incompetency are certainly unusual findings. For example, tabloids and entertainment “news” programs feature full-lipped stars such as Angelina Jolie, Paris Hilton, Gisele Bündchen, Milla Jovovich, Katie Holmes, Jessica Garner, Nick Lachey, Jessica Simpson, Prince

William, Halle Berry, Anna Nicole Smith, Charlize Theron, and George Clooney. Yet, they all might be considered to have “flat profiles” despite never having been subjected to “extraction orthodontics”. In addition, those who are said to have the much sought after “wide, Hollywood” smiles (Brad Pitt, Angelina Jolie, Farrah Fawcett, Cameron Diaz, George Clooney, and above all, Julia Roberts) also display the largest so-called “dark spaces at the buccal corridors”⁷⁰.

These contradictory findings and the lack of evidence should rouse suspicion for routine treatments designed to avoid extraction by expansion, with the specific intent of preventing “negative spaces” and flat faces. This would seem obvious when smile esthetics for extraction and non-extraction treatments are similar^{71,72,73,74,75,76,77} and when the common folk (the “end-users” of orthodontic services) are not particularly discerning or even concerned^{78,79}.

Extractions, in themselves, are a rather innocuous procedure compared with the alternatives of producing bimaxillary protrusions, incorporating unusual expansive treatments, elaborate methods of distalization, or surgery. This is especially true if the alternatives offered could result in potentially unstable or periodontally compromised results. If mini-screw-based anchorage is added to this mix, then the added predictability of tooth movement (i.e. controlling the amount of incisor retraction or posterior protraction) seems to reduce arguments about “extractions” to insignificance.

8.2.3 Maximum Retraction

The most obvious application for mini-screw anchorage is for those patients who present with both severe crowding and protrusion, as absolute anchorage and maximum retraction are required. Often with traditional mechanics, dental crowding is eliminated but anchorage may have been lost prior to any change in the protrusion. This is most disconcerting in the treatment of a Class II malocclusion if anchorage loss during resolution of crowding and protrusion results in molars that are still in Class II at the conclusion of treatment (despite the orthodontist’s best efforts at anchorage control). It would seem that TAD-based differential forces for those patients that exhibit severe crowding and/or protrusion (i.e. requiring absolute anchorage) are those that would be the most obvious benefactors.

8.2.4 Avoiding Retraction: Maintain Incisor/Lip Position

On the opposite end of the spectrum are situations in which no change in incisor or lip position is desired, although circumstances such as substantial crowding or missing teeth may necessitate significant tooth movement. Occasionally, the closure of spaces (e.g. generalized dental spacing, extraction spaces, or congenitally missing dental spaces) may require anchorage that must be every bit as “absolute” as for a patient with bimaxillary protrusion. In these situations, mini-screws permit predictable resolution of crowding, retraction of teeth to just eliminate the discrepancy, and then they can be used to support or maintain the A-P position of the incisors as posterior teeth are moved mesially. Although many of the critics of extractions curiously accept the notion that orthodontic treatment must, of necessity, result in retraction (“backwards-pushing-mechanics”); orthodontists *can* move teeth in *both* directions. With mini-screws, this becomes exceedingly effective and efficient. Deciding where we specifically *want* to move the incisors for function and esthetics now becomes the critical issue, not whether or not to extract.

8.2.5 Extractions: Which Teeth?

Can the advent of TAD-based mechanics make a difference in the selection of teeth for extraction? Sometimes a compromise is required in this decision process. Occasionally, an unrestored, “virgin” tooth may be extracted instead of teeth that have had endodontic treatment and/or substantial restoration. For example, healthy first premolars may be removed, instead of restored second premolars or first molars, in a traditionally treated maximum anchorage situation. In other circumstances, second premolars are extracted, instead of first premolars, with the intent of limiting the amount of incisor retraction. All of these treatment-planning decisions may need to be re-thought in a world with mini-screw anchorage and efficiently applied directional forces.

There should be no fear of extracting premolars if properly designed mechanics are at work⁸⁰. If, on the contrary, there is no plan or goal for the final position of teeth, then adding mini-screw mechanics might produce some

horrific, iatrogenic consequences. For example, teeth could be “dragged-off” or out of the alveolar bone or dramatic over-retraction of incisors could produce unintended profile effects. It would seem that the use of something like the visual treatment object (VTO)⁷⁷ would finally become an important aspect of treatment planning. This is because “predictions” of tooth movement with mini-screws becomes much more accurate. It certainly seems apparent that with proper planning for the incorporation of mini-screws that the seemingly eternal arguments against extraction are finally moot. Extraction spaces can now be closed with greater predictability (more effective retraction; maintaining incisor position; or even improving incisor position) to enhance or at least maintain facial esthetics during a course of “straightening teeth”.

8.2.6 Another Alternative for Borderline Extraction Patients?

That is what learning is. You suddenly understand something you've understood all your life, but in a new way. Doris Lessing

There has been no proof of any “better” alternatives for producing the amount of space that the extraction of premolars provides. In other words, there appears to be no reliable substitute for extractions for patients who need it: those with crowding and/or protrusion. That leaves us with the “borderline” situation, where the extraction decision could go either way. Can this borderline extraction decision be altered using mini-screws?

Distal *en masse* movement or bodily retraction of either the entire maxillary and mandibular dentition has been described as possible when supported by mini-screw anchorage^{67,68}. In light of these findings, could borderline dental crowding (3–4 mm) be more reliably corrected using TADs, rather than using extractions (i.e. premolars or an incisor), two-phase bimaxillary expansion, or interproximal reduction? The limitations and effectiveness of this type of retraction are yet to be documented. For example, what role would third molars play and what is the long-term stability of this new type of “backwards-pulling mechanics?” Therefore, it would seem that mini-screw based “bimaxillary retraction” has at least a theoretical

basis and may eventually be a viable non-extraction, non-expansion approach for mild-to-moderate crowding. As such, it is certainly worthy of future investigation.

8.2.7 Conservative Resolution of Crowding: Leeway Space

Hays Nance defined leeway space as “the differential in tooth widths between deciduous and permanent buccal teeth”¹²⁰. During the transition from the mixed dentition, this so-called “e” space is lost, primarily due to mesial migration of the first permanent molars. If the mandibular leeway space can be conserved, *Gianelly*⁸⁶ has suggested that at least 77% of patients with crowding (featuring favorable profiles that do not require retraction) may be resolved without expansion or extraction – and it has shown to be very stable⁷⁷. The basic mandibular lingual arch or a lip bumper^{77,78,81} have been recommended to hold the leeway space, but both are somewhat unpredictable.

Mixed dentition patients with sufficient leeway space to permit the elimination of mandibular crowding may benefit from mini-screw anchorage to effectively and efficiently use that space. Timing is everything in this scenario, as treatment to actually utilize the leeway space should be initiated just before the loss of the second primary molars. If enough interradicular space is available between the first and second mandibular molars, then mini-screws can be inserted to serve for either direct or indirect anchorage. After the primary second molars are exfoliated or extracted, then elastic or coil springs can be attached to the mini-screws to retract the first premolar into the available leeway space: up to the width of the erupting second premolar. As an alternative, an attachment on the first permanent molar can be “tied” with a stainless steel ligature to the mini-screw. In turn, the retraction forces are applied from the molars (indirect anchorage) to the premolars.

In many patients in the mixed dentition, the second permanent molars are unerupted and/or the bone density is poor between the molars, so an alternative mini-screw site should be chosen. Mini-screws can be easily placed between the mandibular lateral incisors and canines. A sectional bayonet wire or “jig” can be fabricated with a compressed open-coil spring to push the first premolar distal, away from the

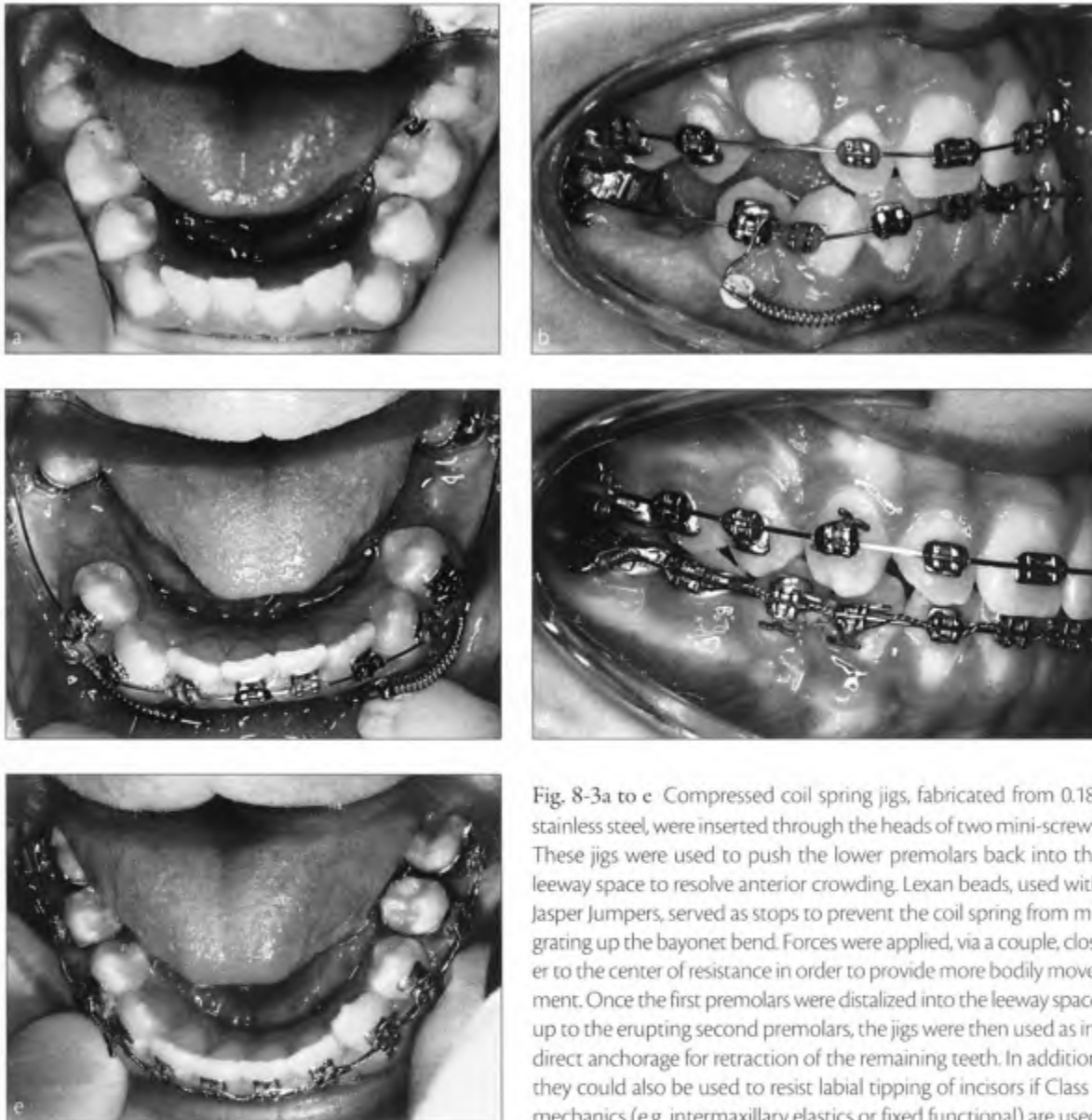


Fig. 8-3a to e Compressed coil spring jigs, fabricated from 0.18" stainless steel, were inserted through the heads of two mini-screws. These jigs were used to push the lower premolars back into the leeway space to resolve anterior crowding. Lexan beads, used with Jasper Jumpers, served as stops to prevent the coil spring from migrating up the bayonet bend. Forces were applied, via a couple, closer to the center of resistance in order to provide more bodily movement. Once the first premolars were distalized into the leeway space, up to the erupting second premolars, the jigs were then used as indirect anchorage for retraction of the remaining teeth. In addition, they could also be used to resist labial tipping of incisors if Class II mechanics (e.g. intermaxillary elastics or fixed functional) are used.

mini-screw (Fig. 8-3). As a fourth alternative, a supporting wire segment can be attached to the mini-screw and extended back to the first permanent molar to act as indirect anchorage for retraction of the first premolars (Fig. 8-4).

After crowding is resolved, then the mini-screws can be used to counteract any reactive forces that could result in adverse labial flaring of the lower incisors during leveling of the curve of Spee or from Class II mechanics (i.e. Class II intermaxillary elastics, fixed functional appliances). Could the introduction of TAD-supported anchorage for the management of the leeway space provide a more predictable and efficient method to resolve borderline crowding without extraction, unstable expansion, or

lower incisor proclination, in a single phase of orthodontic treatment? Time and research will tell, but the outlook is promising.

8.3. The Role of Mini-screws in Class IIs

Next to crowding, Class II is the second most prevalent problem presenting for orthodontic treatment. The resolution of Class II involves "pushing" the maxilla or maxillary dentition posteriorly and/or "advancing" the mandible (or some combination of both). Mini-screw-supported anchorage can facilitate any of these treatment alternatives.

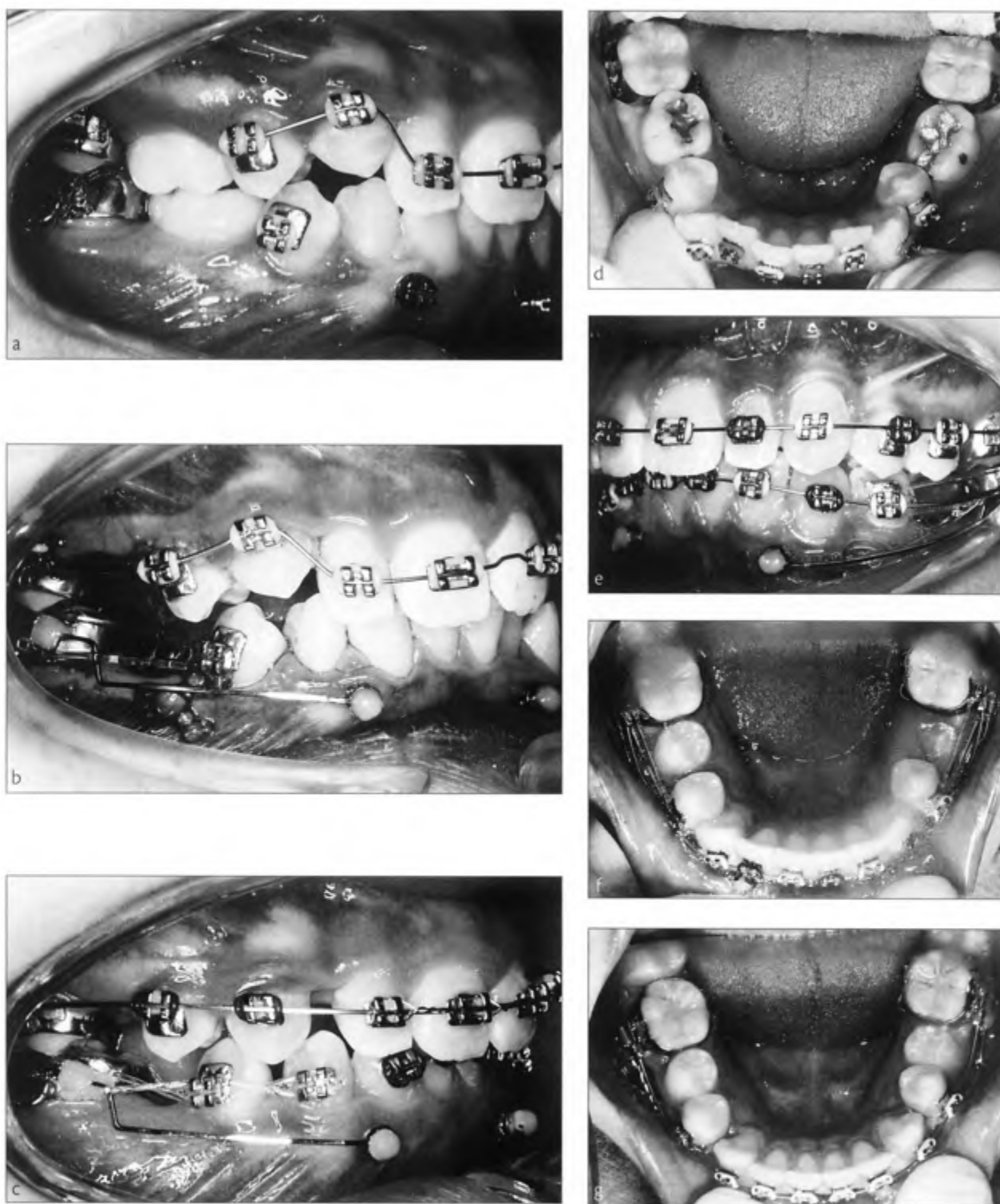


Fig. 8-4a to g Effective use of leeway space. Two mini-screws were placed in the anterior mandibular alveolus for indirect anchorage support of the first molars. Sectional wires (0.018" x 0.018") extended from the mini-screws to the molars were used to maintain the leeway space as crowding was corrected. Two patients are shown (a to c, and d to g) where the leeway space was efficiently utilized to resolve crowding without expansion or extraction in a single phase of comprehensive orthodontic treatment.

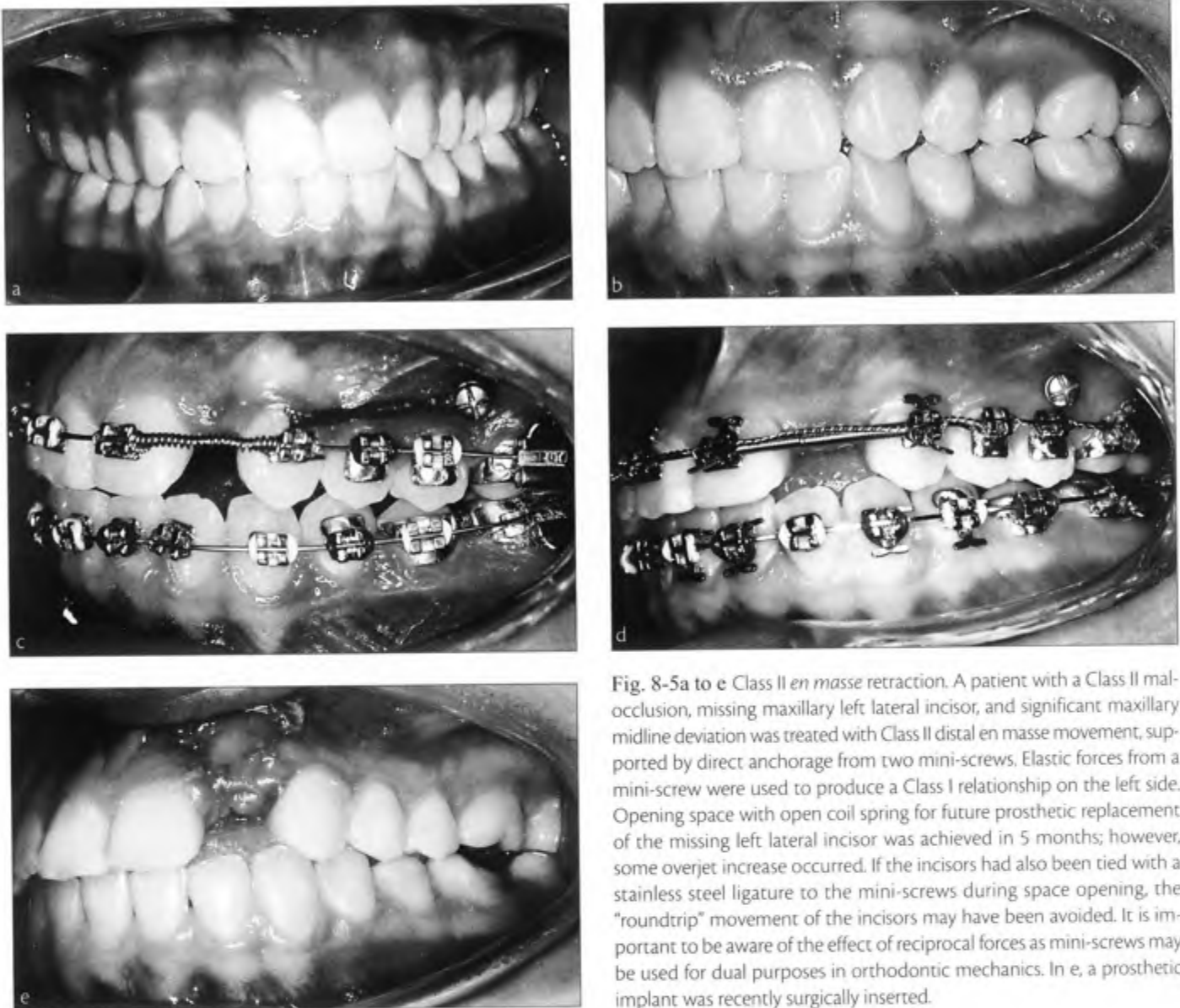


Fig. 8-5a to e Class II *en masse* retraction. A patient with a Class II malocclusion, missing maxillary left lateral incisor, and significant maxillary midline deviation was treated with Class II distal *en masse* movement, supported by direct anchorage from two mini-screws. Elastic forces from a mini-screw were used to produce a Class I relationship on the left side. Opening space with open coil spring for future prosthetic replacement of the missing left lateral incisor was achieved in 5 months; however, some overjet increase occurred. If the incisors had also been tied with a stainless steel ligature to the mini-screws during space opening, the "roundtrip" movement of the incisors may have been avoided. It is important to be aware of the effect of reciprocal forces as mini-screws may be used for dual purposes in orthodontic mechanics. In e, a prosthetic implant was recently surgically inserted.

8.3.1 Class II: Maxillary *en Masse* Retraction

Distal *en masse* movement of the maxillary dentition has been reported for Class I non-extraction patients when using mini-screw anchorage⁶⁷. What, then, is the likelihood of enough retraction of the maxillary dental arch to correct some Class II malocclusions?

Jeon et al⁶⁹ published a case report of Class II non-extraction distal *en masse* retraction of the maxillary dentition using mini-screws. Park

and his colleagues^{66,69} published both a case report and also the results for thirteen patients where both maxillary and mandibular retraction were accomplished, with a 90% screw survival rate. In these cases, mini-screws were positioned between the roots of first molars and second premolars for direct anchorage support for the distal retraction of the entire maxillary dentition to Class I (Fig. 8-5 and 8-6).

Can mini-screws also support some degree of *en masse* retraction or, at minimum, prevent adverse anchorage loss in treatments featuring

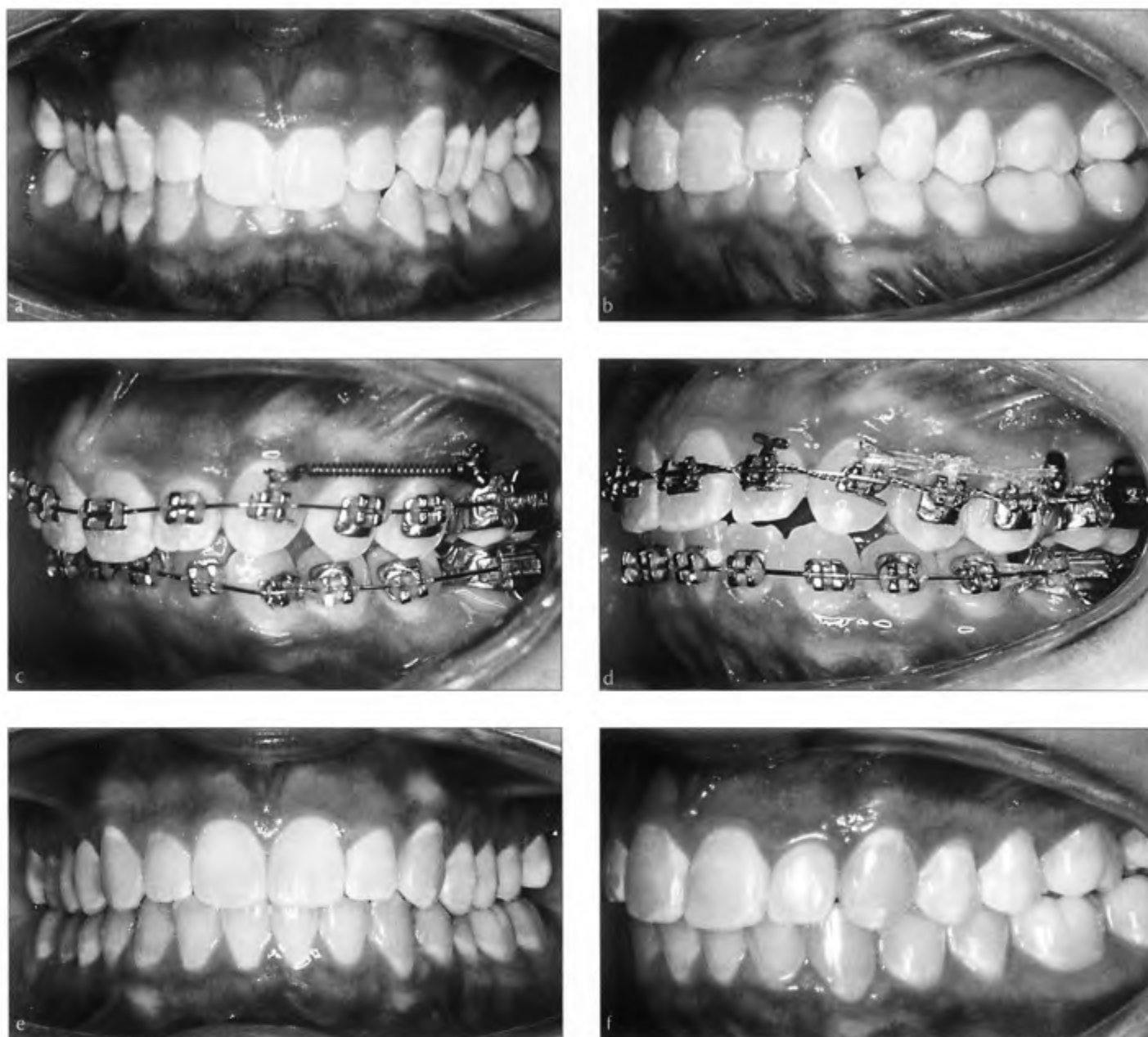


Fig. 8-6a to f Class II *en masse* retraction. A 16-year-old female with a unilateral Class II relationship and associated midline deviation was treated using mini-screw-based maxillary distal *en masse* retraction. A mini-screw, inserted between the first molar and second premolar (at the mucogingival junction), was used for direct anchorage support.

"clear aligners" like Invisalign? Intra-arch or inter-arch intraoral elastics may be applied from mini-screws to notches or buttons on the aligners. An added advantage of mini-screw-supported elastics with aligners is one of intrusive forces in deep overbite cases and to also provide pressure for proper seating and "tracking" of the aligners (Fig. 8-7), especially when combined with active seating of the trays using Aligner Chewies* (Glenroe Technologies, Bradenton, FL, USA)¹³.

8.3.2 Class II: Molar Distalization

Maxillary molar distalization has grown as a popular adjunct for Class II correction since the 1990s⁴³. A menagerie of appliances or "gadgets", designed to push upper molars back into a normal Class I position, have entered the orthodontic marketplace. Unfortunately, all of these devices have drawbacks, such as anterior anchorage loss, tipping or extrusion of teeth, and/or dependence upon unpredictable pa-

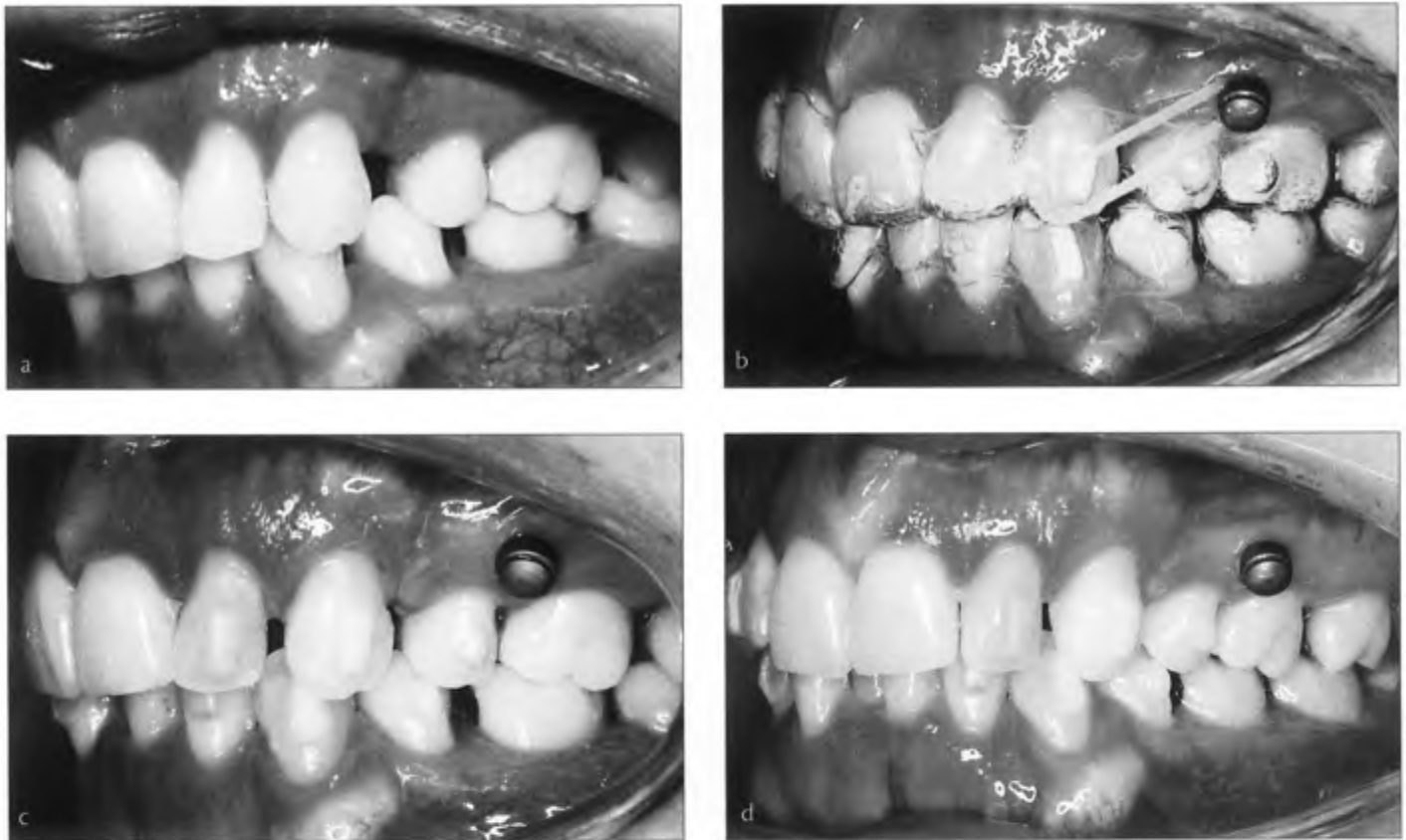


Fig. 8-7a to d Mini-screw-supported Invisalign (Align Technologies, Santa Clara, CA). Open extraction sites, crowding, and deep overbite still remained after previous, incomplete orthodontic treatment. Two mini-screws (with healing caps) were placed between the maxillary first molars and second premolars to provide indirect anchorage support for 1) space closure/retraction, 2) anterior intrusion, and 3) proper "tracking" of Invisalign trays. "Class I" intramaxillary elastics were worn from the TADs to "notches" cut into each aligner tray. Treatment is in progress.

tient cooperation. The addition of mini-screws to these devices to reduce the effects of the negative aspects would seem to be an obvious benefit^{12,18,22,30,48,50}.

8.3.2.1 Anchorage Loss

One of the best documented and most reliable devices for molar distalization is the Distal Jet^{12,18,30}. As the maxillary molars are pushed distally with the Distal Jet®, spaces open mesial to the molars. Although much of this space is due to the desired distal movement of the molars, reciprocal forces are also directed to the premolars (included in the construction framework), resulting in 15–55% anchorage loss¹². More anchorage loss and 10° of incisor "flaring" was noted when the Distal Jet was used during the leveling process with maxillary pre-adjusted brackets^{12,30}. It would seem that there is no advantage to incorporating full-fixed braces in an attempt to enhance anchorage. In other words, upper braces should be added after distalization is

complete^{12,18,30}. This confirms *Melsen's* contention that there is no anchorage value to previously mobilized teeth⁵⁷. Perhaps the addition of mini-screw anchorage with either molar distalization or mandibular advancement (e.g. fixed functionals) may help to reduce the anchorage loss inherent to either Class II corrective mechanism.

8.3.2.2 Mini-screw-supported Distalization

Devices Using Spring Force

*Escobar et al*²⁹ reported no anchorage loss with a TAD-supported Pendulum distalizer; however, the time required for molar correction (7.8 months) and the amount of molar tipping (11.3°) was not reduced compared to other methods¹⁷. *Öncag et al*⁶² also found substantial molar tipping with poor marginal ridge match when osseointegrated implants were incorporated into the Pendulum. In addition, whenever an acrylic *Nance* palatal "button" is part of a distalizing appliance, there is a concern for soft

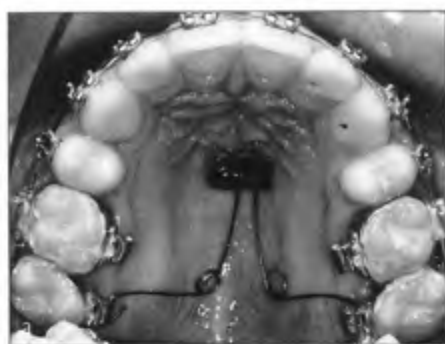


Fig. 8-8a Mini-screw-supported molar distalizing arms attached initially to the second molars using light-cured adhesive.

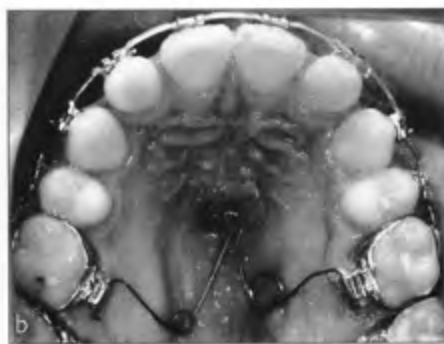


Fig. 8-8b New springs were subsequently attached to the first molars to continue the distalizing process. The left spring had to be exchanged by removing the composite. This mechanism requires the use of full fixed appliances to control the movement.

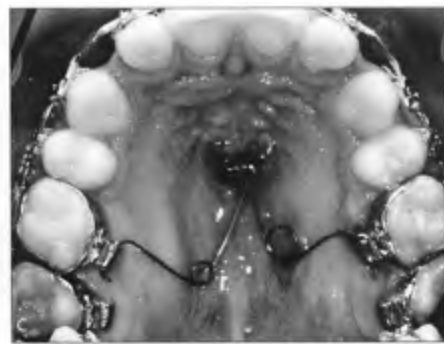


Fig. 8-8c At the completion of distalization, the springs are then used to stabilize the molar position during subsequent retraction of the remaining teeth.

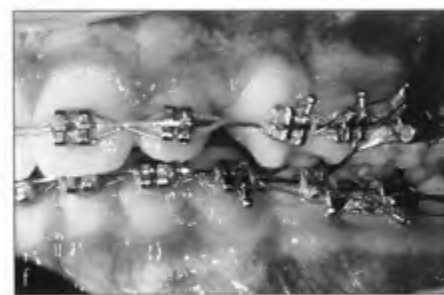
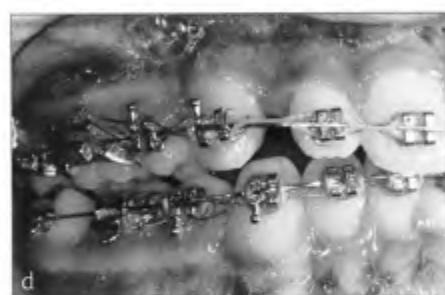


Fig. 8-8d to f Front and side views after distalization was completed.



Fig. 8-9a and b Distal Jet modified to include anchorage support from a mid-palatal mini-screw. The mini-screw can be inserted through a hole in the traditional Nance acrylic button or connected or "keyed" into the skeletonized framework.

tissue compression and food/debris accumulation. If an anchorage screw is inserted through, bonded into position (Fig. 8-8), or "keyed-into" any part of the distalizing device (e.g. inserted through the *Nance* button; Fig. 8-9) and it is lost prematurely, the entire appliance may need to be removed and re-fabricated to accommodate the placement of an implant in a new location, rather than replacing it in the site where the previous one "failed".

Devices using Intermittent Force

Some molar distalization appliances apply intermittent forces (Fig. 8-10). One example, the *Frog* appliance⁸¹, produces distal forces using a jackscrew (embedded in an acrylic *Nance* button) that requires consistent and periodic activation (Fig. 8-11). Holes for the insertion of mini-screws in the anterior palate are drilled through the acrylic button or inserted into a metal framework. After the device is seated and the mini-screws are placed, then light-cured

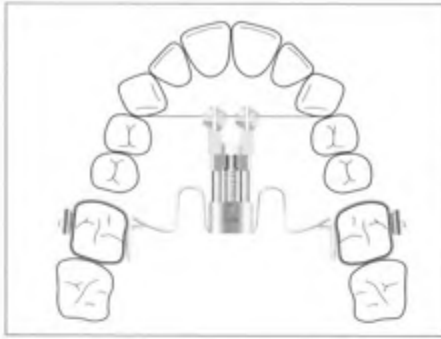


Fig. 8-10 Mini-screw-supported *Frog* molar distalizing appliance. Mini-screws are inserted into specific holes in the anterior portion of the framework. Turning the jackscrew may be done by the patient or during regular visits with the specialist. At the conclusion of distalization, the appliance then serves as anchorage for retraction of the remaining teeth. No dental support from the premolars is necessary as only skeletal anchorage supports both processes.



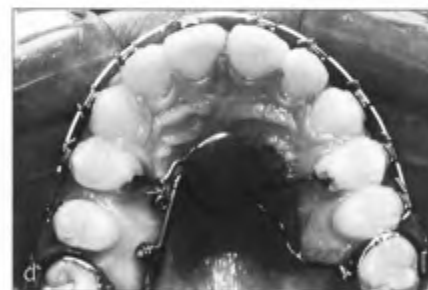
Fig. 8-11 Paramedian mini-screws are inserted prior to impressions for fabrication of the *Frog* appliance.



Fig. 8-12 After the distalizing device is inserted.



Fig. 8-13a to c Multiple variations of mini-screw-supported Distal Jet appliances (photographs by S. Jay Bowman, Gero Kinzinger, and Stefano Velo).



"flowable" composite is used to seal those holes (Fig. 8-12). Although the patient can activate the device by turning the jackscrew with a "key", this introduces reliance upon patient compliance for success. As a result, the orthodontist may recommend regular return office visits to provide the activation.

8.3.2.3 Mini-screw-supported Distal Jet

Mini-screws, placed in the anterior palate, have been used in conjunction with the Distal Jet (Fig. 8-13 and 8-14) and other distalization devices^{13,22,29,33,46,48,51,62,83}. Although there are no roots to contend with in the palate, persistent and intermittent forces from the tongue could contribute to more frequent failure of the mini-screw. For these reasons, mini-screws have also been inserted posterior to the appliances and then tied to them with a stainless steel ligature

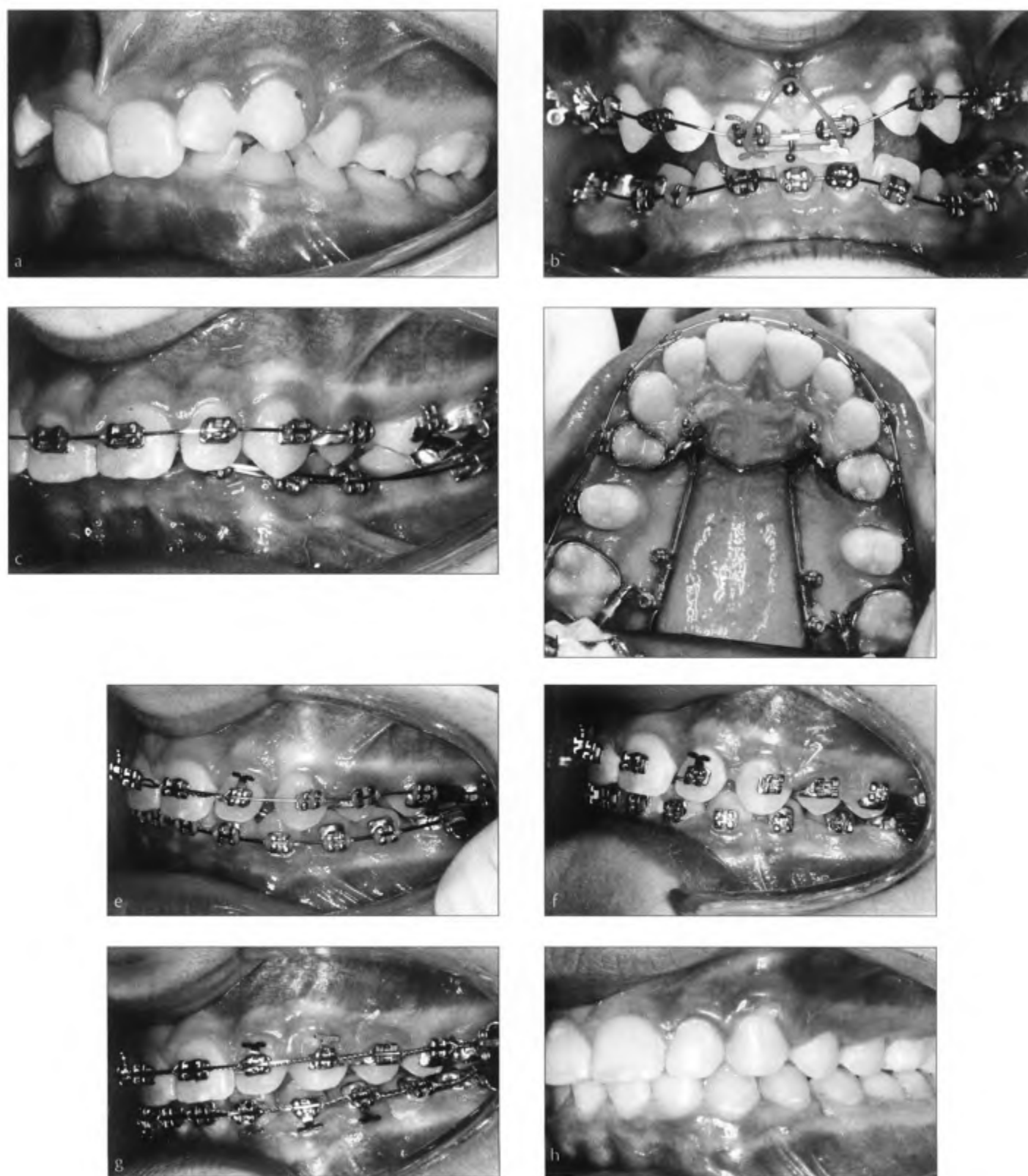


Fig. 8-14a to h Mini-screw-supported Distal Jet. An adolescent with a Class II Division 2 malocclusion and deep bite was treated with a mini-screw-supported Distal Jet appliance. Two mini-screws, placed in the anterior palate between the canines and lateral incisors, were tied with stainless steel ligatures to a skeletonized Bowman Modification Distal Jet (AOA Laboratories, Racine, WI). A "super-Class I", over-corrected molar relationship, was produced in 7 months. Leveling, bite-opening, and a Class I cuspid relationship was achieved in 12 months. Only simple maxillary space closure remains. The mini-screws reduced the reciprocal anchorage loss that would normally be seen with the Distal Jet. Total treatment was 27 months.

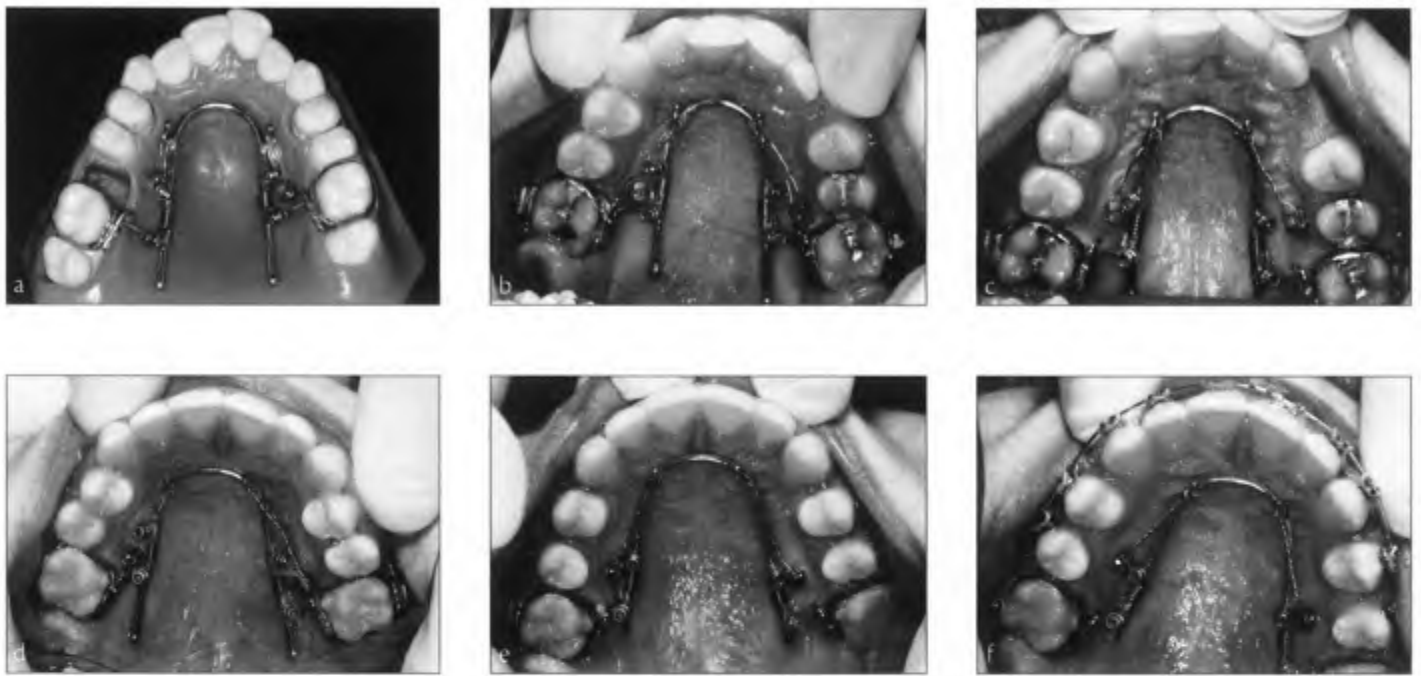


Fig. 8-15a to f The Horseshoe Jet (AOA Laboratories, Racine, WI, USA) is a skeletonized version of the Bowman Modification Distal Jet. It is supported by two mini-screws inserted at an angle into the lingual slope of the maxillary alveolus. Stainless-steel ligatures are tied from the mini-screws to hooks on the U-shaped tracking wire to provide indirect anchorage for molar distalization without anchorage loss. Since the root of the second premolar is angled buccally and the first molar has only one palatal root, there is less concern for iatrogenic damage to the roots of these teeth when inserting mini-screws into this wide interradicular space. In addition, the roots of the second premolars are free to move distally, "bypassing" the mini-screws, due to traction from the transseptal fibers. (b,c) Thirteen-year-old Class II patient with Horseshoe Jet and progress of distalization after 5 months; (d-f) twelve-year-old Class II patient, distalization completed in 7 months. The distal set-screws were then locked. This converted the appliance into a mini-screw-supported lingual arch. Maxillary pre-adjusted appliances (Butterfly System, American Orthodontics, Sheboygan, WI, USA) were placed and active retraction of the remaining teeth was supported by indirect anchorage from the lingual arch. Please note that the addition of dental anchorage support arms to the premolars is not required and may introduce anchorage loss due to the inherent flexibility of the components.

wire (Fig. 8-13)¹³. In this configuration, the stability of the screw can be easily tested and, if necessary, it can be easily removed and replaced without fabricating a new appliance^{13,46}. Inserting mini-screw implants between the maxillary first molar and second premolar or between the two premolars, either on the buccal or lingual (Fig. 8-13) of the alveolus, is another option^{13,49,52}. After distalization has been achieved, the mini-screws will need to be removed and replaced in another location (e.g. between the first and second molar or just mesial to the distalized first molar) as it may not be possible to retract the second premolar past the original mini-screw position.

8.3.2.4 A Better Alternative

For something to endure, it must be unique.
Dr. Ferdinand Porsche

George Anka⁶ has suggested that a more favorable mini-screw insertion point is on the palatal side of the alveolus: between the maxillary first molars and second premolars (Fig. 8-15). Poggio et al⁷¹ have noted that this location has the greatest expanse of interradicular bone on either side of the maxillary alveolus. When the mini-screw is angled (30–45°) to the sloping surface of the alveolus, the cortical bone thickness is from 1.7 ± 0.5 mm to 2.2 ± 0.4 mm for adults; certainly sufficient for mini-screw support⁷⁶. Sonis⁷⁸ found a similar amount of cortical bone (about 1.7 mm) for adolescents, patients who would most often benefit from this type of Class II treatment (Fig. 8-16).



Fig. 8-16a to d The lingual alveolus between the maxillary second premolar and first molar is a favorable site for mini-screw insertion. There appears to be adequate cortical thickness and substantial interradicular space (CBCT scan courtesy of Andrew Sonis).

Another advantage of this lingual site is that the palatal root of the maxillary second premolar is often angled towards the buccal, away from the mini-screw. In addition, the palatal root of the first molar is often rotated posteriorly, providing substantial space between the roots of these two teeth. This may result in: 1) less potential for iatrogenic damage when inserting screws; 2) a mini-screw can be positioned more distal, closer to palatal root, pro-

viding more space for premolar retraction before a screw might be encountered; and finally, 3) the second premolar root is more likely to miss the angled mini-screw after distalization, during the subsequent retraction of the other teeth (Fig. 8-15). In other words, the screws may not need to be moved to a different position after distalization or when the remaining teeth are retracted.



Fig. 8-17a to c Activation and conversion of the *Bowman Modification and Horseshoe Jet* (AOA Laboratories, Racine, WI, USA). The posterior hex screw is loosened one quarter turn counterclockwise to initiate distal molar movement with the *Horseshoe Jet*. The anterior activation collar is pushed back to compress the superelastic coil spring and the hex screw is then locked onto the tracking wire. After a Class I molar relationship is reached, only then is the posterior hex screw locked onto the tracking wire. The two locks help to prevent unwanted mesial movement of the molars. The premolar supporting wires are then sectioned with a handpiece and crosscut fissure bur. Note: the superelastic coil springs do not have to be removed. The resulting mini-screw-supported lingual arch for the *Horseshoe Jet* version also provides anchorage for retraction of the other teeth: one appliance serves two purposes.



Bowman designed a modification of the Distal Jet appliance (Horseshoe Jet, AOA Laboratories, Racine, WI, USA)* whose anchorage is solely based on mini-screws (Fig. 8-15)¹⁵; premolar support wires (with bonded occlusal rests) may also be constructed from the framework to reduce potential tipping (Fig. 8-15). Unfortunately, this dental support seems to introduce the risk of some anchorage loss due to the inherent flexibility of the components. There is more favorable bone, more attached gingiva, and less likelihood of touching a root at this palatal insertion point, and as such, there is a lower incidence of TAD failure.

Often, only a profound topical anesthetic (e.g. 20% TAC Alternate) may be required to place mini-screws in this palatal location, although some patients might require an infiltration with a typical dental anesthetic. This simplicity is in stark contrast to the often-painful incisive foramen injection required when mini-screws are placed in the anterior palate. *Maino et al*¹⁶ also described the advantage of using mini-screws in this same lingual alveolar location; however, the anchorage system they employed required support from the first premolars and the forces were applied at the height of the crown of the molars; possibly resulting in more tipping.

The acrylic *Nance* button of the original Distal Jet has been eliminated for the mini-screw supported Horseshoe Jet. Anchorage is derived from tying stainless steel ligature wire from the mini-screws to hooks on the horseshoe-shaped tracking wire (Fig. 15). At the completion of distalization (i.e. over-correction into a partial Class III or "super" Class I molar relationship), the distal setscrew is locked onto the tracking wire to stop the process (Fig. 8-17). In contrast to the original Distal Jet, the open coil spring is not removed. However, if premolar supporting arms are used, they must now be sectioned using a crosscut fissure or diamond bur (Fig. 8-17). Now, the Horseshoe Jet has been converted into a mini-screw - supported lingual arch. The indirect anchorage to the molars from this mini-screw-supported lingual arch can then be used for retraction of the remaining maxillary teeth. In this manner, one mini-screw-based appliance serves two purposes: indirect anchorage for molar distalization and also for retraction of the rest of the dentition. It remains for research to determine if treatment time and effectiveness have been improved with this mechanism.

8.3.3 Intermaxillary Approaches to Class II Corrections

Traditional mechanics for Class II correction have focused on the intent to inhibit maxillary development (headgear), "stimulate" mandibular growth (functional appliances), or some amalgamation of those concepts (Class II elastics, headgear/functional combination). Each of these approaches features their own inherent unintentional side effects (tipping, anchorage loss or incisor "flaring", extrusion) or is limited by patient compliance issues.

8.3.3.1 Mini-screw-supported Intermaxillary Elastics

Class II elastics (Baker anchorage) are one of the most cost-effective and easiest methods for reducing a Class II malocclusion. Unfortunately, elastics may alter the occlusal plane (by extruding lower posterior and upper anterior teeth), may produce unintentional labial "flaring" of the lower anterior teeth, and are absolutely compliance-dependent. Class II elastics result in a contribution from both maxillary and mandibular dentoalveolar changes, along with some limited mid-face growth inhibition and mandibular enhancement (at least in growing individuals). Placing mini-screws in the posterior mandible (e.g. between first and second molars or between first molars and second premolars) and attaching them to full-fixed appliances can resist the extrusive and protractive forces of Class II elastics that are hooked to mandibular molar attachments. As a consequence, the addition of Class II *en masse* mini-screw-supported retraction or TAD-based molar distalization, would help to reduce patient's exposure to the adverse effects from Class II elastics and negate the majority of compliance issues associated with them.

8.3.3.2 Addressing the Mandible for Class II Correction

The concept of advancing the mandible, with the intent to enhance its growth, was described prior to the turn of the 20th Century. Although the "pieces and parts" have evolved through the introduction of a diverse collection of machinations during the ensuing century, the concept is still the same: push or hold the mandible forward and growth modification is

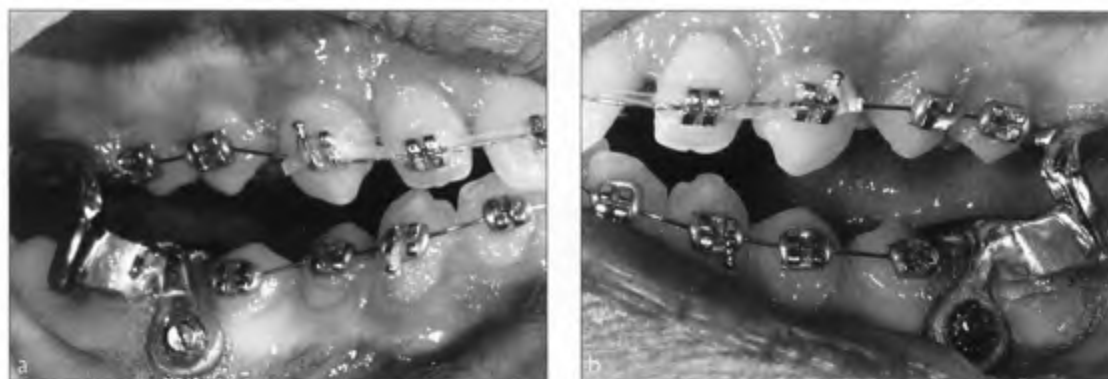


Fig. 8-18a and b Mini-screws are inserted into the mandibular cortical plate between the first molars and second premolars. A modified FMA appliance is constructed to use the mini-screw for anchorage support to prevent adverse changes in the mandibular dentition (photos by Dr. B. Ludwig).



Fig. 8-19 Mini-screw supported Williams appliance. The intent is to limit dentoalveolar side effects, especially flaring of the lower incisors (photo by Dr. B. Ludwig).

said to occur. Despite the fact that it matters little if you “lean” on the mandible or the maxilla, the amount of mandibular response and, more importantly, the end results, are about the same. As such, often selecting to address the maxilla or the mandible for non-surgical correction of Class IIs may be thought of as a practice management decision. A fixed functional appliance (e.g. *Herbst*, MARA, *Jasper Jumpers*, etc.) might be chosen because of wishful thinking that “more” mandibular enhancement may result.

Regrettably, all fixed functionals tend to produce some level of adverse labial flaring of mandibular incisors^{74,75}. This may give way to either a detrimental effect in lip position, a reduction in the amount of mandibular advancement that is possible, or inherent instability. AlQabandi et al⁷ described 6–7° of lower incisor labial tipping occurs even when leveling the curve of Spee with fixed appliances. As a consequence, many pre-adjusted appliance prescriptions feature lingual crown torque to counteract this effect⁴⁴. Perhaps the addition of mini-

screw mandibular anchorage to assist in reducing the iatrogenic effects of these devices could enhance their correction potential.

Mini-screw-supported MARA (Mandibular Anterior Repositioning Appliance)

Edward Angle first introduced a molar-based mandibular protraction device nearly a century before today’s so-called MARA device^{10,28}. The fabrication of the MARA can be modified to incorporate anchorage support from mini-screws inserted through the fixture and then attached with light-cured flowable composite (Fig. 8-18).

Mini-screw-supported Fixed Functionals

The *Herbst* appliance (Fig. 8-19)^{65,76} can be combined with mini-screws to help avoid undesirable protrusion of the lower incisors. This method of passive stabilization can also be applied to other fixed functional appliances^{65,47} like the *Jasper Jumper*, *Sabbagh Universal Spring*, etc.

8.3.3.3 Future Investigations

What, if any, of these previous mechanisms could be strictly skeletally anchored without any connection to the dentition? Would more maxillary growth inhibition or mandibular enhancement result? Perhaps in the near future these questions can be answered as a new generation of devices (or modification of current appliances) is attached directly to some type of cortical anchors with no support from the teeth. Another future alternative may be localized biochemical inhibition of the movement of specific teeth (artificial and temporary "ankylosis") using some type of osteoclastic inhibitor. These immobilized teeth would then provide temporary anchorage (possibly combined with mini-screws) to resist adverse reactive forces associated with specific orthodontic mechanisms.

8.4 The Role of Mini-screws in Class IIIs

Although treatment for Class III malocclusions cannot really be considered simply as inverted or "upside down" Class II mechanics, some of the principles for mini-screw anchorage can be measured from that perspective.

8.4.1 Class III: Maxillary *en Masse* Protraction

In milder versions of Class III malocclusions, some degree of maxillary protraction has been historically used for correction. Protraction facemasks, compressed coil springs (abutted against molars) to push upper anterior teeth labially, and Class III elastics have all been used with varying degrees of success in resolving Class III malocclusions.

Placing TADs between teeth in the mid-portion of the maxilla (on the lingual or buccal) can be used to provide direct anchorage to pull the entire dentition anteriorly. In addition, protraction elastic forces can be applied from a transpalatal arch to mini-screw(s) inserted in the anterior palate (Fig. 8-20 and 8-21). As an alternative, screws can be placed in the palatal alveolus between the maxillary first molar and second premolar (as was previously described for molar distalization with the Horseshoe Jet). Elastic chain or coil springs are applied from the mini-screws to a transpalatal arch, constructed

from the distolingual line angle of the first molars. Class III elastics or a protraction facemask can also be added to any of these systems.

8.4.2 Class III: Mandibular *en Masse* Retraction

If the maxillary dentition can be retracted as a whole unit to correct some mild Class II malocclusions, can the mandibular dentition also be retracted to improve some Class IIIs? Paik et al⁶³ described the non-extraction correction of a Class III malocclusion using mini-screw supported *en masse* retraction of the entire mandibular dentition (Fig.8-22). For patients with more discrepancy, mandibular retraction may also be combined with mini-screw anchored maxillary *en masse* protraction.

Sometimes the extraction of a single incisor is required to eliminate an anterior crossbite, underjet, or end-on anterior occlusion. Perhaps mandibular *en masse* retraction can also be used to reduce the necessity of incisor extraction in many of these circumstances.

8.4.3 Mini-screw Adjuncts to Surgery

Pre-surgical preparation for orthognathic surgery often requires some type of dental decompensation along with arch leveling and coordination. Mini-screw anchorage can be used to help achieve these goals; thereby, facilitating or enhancing eventual orthognathic correction. All of the previous applications that have been discussed for mini-screws may play a role in surgical preparation. Then the mini-screws can also be used for intermaxillary fixation as well.

8.5. Transverse Discrepancies

Conventional appliances that are typically used for palatal expansion are constructed with support from the maxillary posterior teeth. As a result, the arch expansion results from a combination of dental and skeletal effects. Although correction of a dental crossbite is often a goal, it is actual expansion at the midpalatal suture that is the desired effect. In a recent tomographic evaluation of rapid maxillary expansion, the skeletal component was less than 2 mm or only about 50% of the total amount of expansion

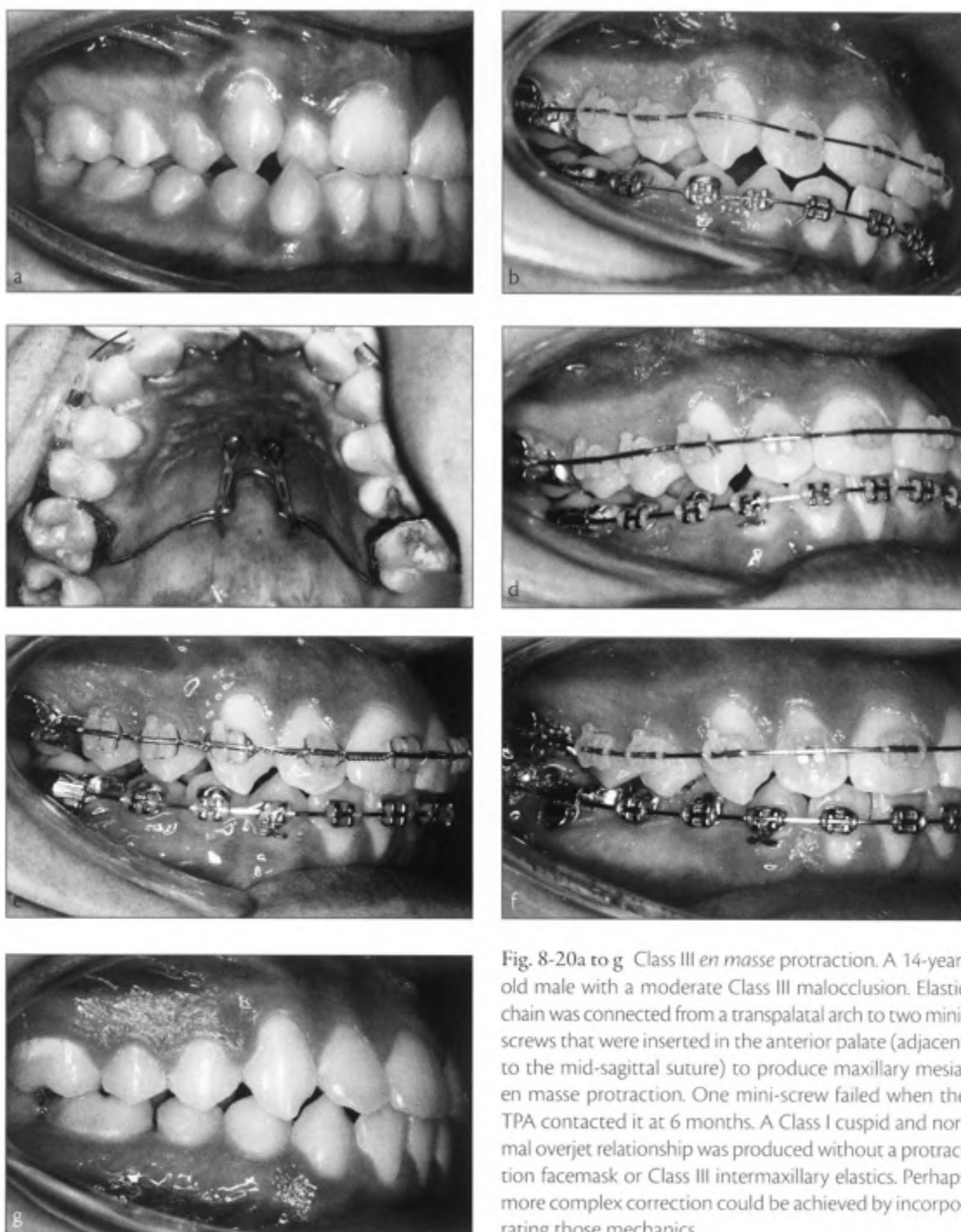


Fig. 8-20a to g Class III *en masse* protraction. A 14-year-old male with a moderate Class III malocclusion. Elastic chain was connected from a transpalatal arch to two mini-screws that were inserted in the anterior palate (adjacent to the mid-sagittal suture) to produce maxillary mesial *en masse* protraction. One mini-screw failed when the TPA contacted it at 6 months. A Class I cuspid and normal overjet relationship was produced without a protraction facemask or Class III intermaxillary elastics. Perhaps more complex correction could be achieved by incorporating those mechanics.

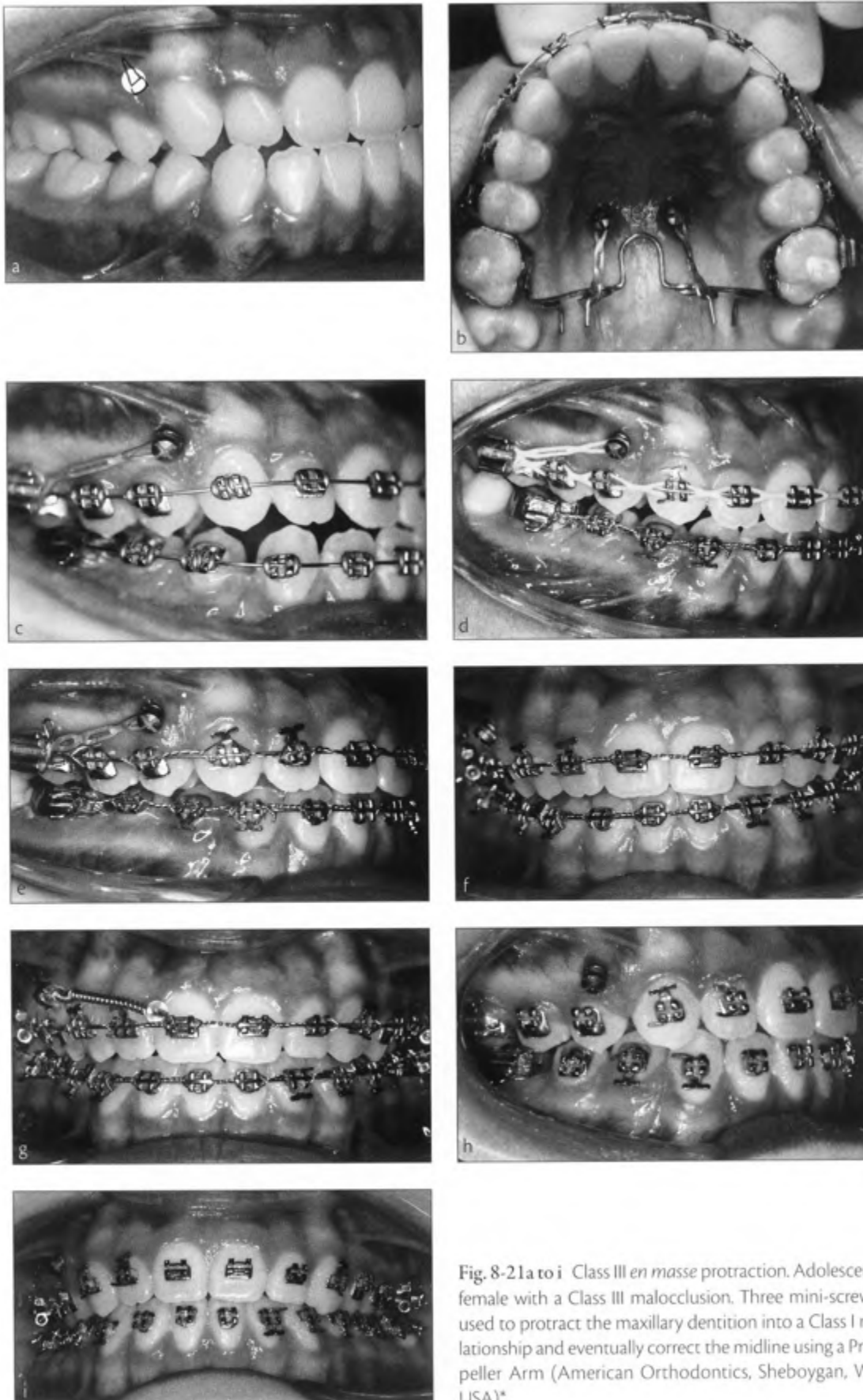


Fig. 8-21a to i Class III *en masse* protraction. Adolescent female with a Class III malocclusion. Three mini-screws used to protract the maxillary dentition into a Class I relationship and eventually correct the midline using a Propeller Arm (American Orthodontics, Sheboygan, WI, USA)*.



Fig. 8-22a to f Class III *en masse* retraction. The maxillary midline diastema was the patient's chief complaint. Labially tipped mandibular incisors prevented any anterior retraction to close the space. Two mini-screws were placed posterior to the most distal teeth in the mandibular arch. Space consolidation, uprighting of mandibular anteriors, and mild distal *en masse* retraction of the entire mandibular dentition was achieved by direct anchorage support from the mini-screws connected with Monkey Hooks (American Orthodontics, Sheboygan, WI, USA)*.

produced³⁰. If, however, expansion forces could be supported only by the two halves of the maxilla, perhaps less tipping of teeth and more effective expansion would result. Several methods of TAD-supported palatal expansion have already been described for transverse discrepancies (Fig. 8-23)³⁰. Future appliance designs and refined methods are sure to follow.

8.6. Single Tooth Issues

Single-tooth movements can be carried out selectively and without adverse effects on other teeth with mini-screw anchorage (Fig. 8-24). Sectional mechanics using direct and indirect anchorage from mini-screws become more predictable and controlled as well. (Fig. 8-25).

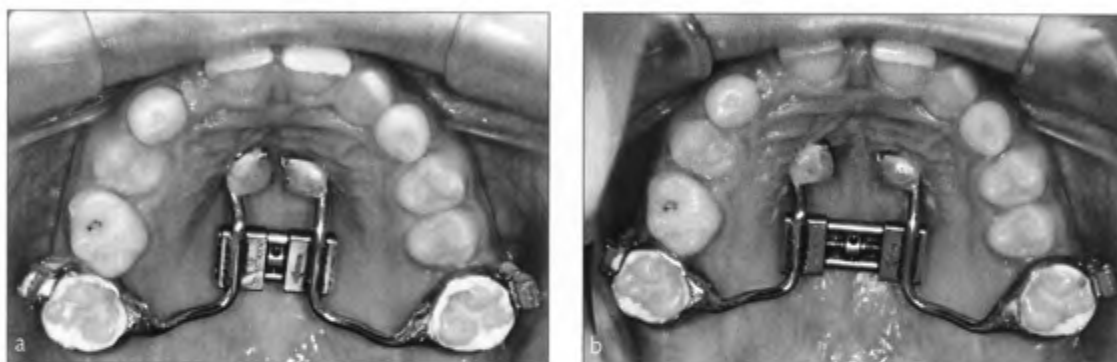


Fig. 8-23a and b Rapid palatal expander utilizing only cortical anchorage from two mini-screws inserted adjacent to the mid-palatal suture. Light-cured adhesive was used to lock the custom appliance over the mini-screws. (photos: B. Wilmes, Düsseldorf).

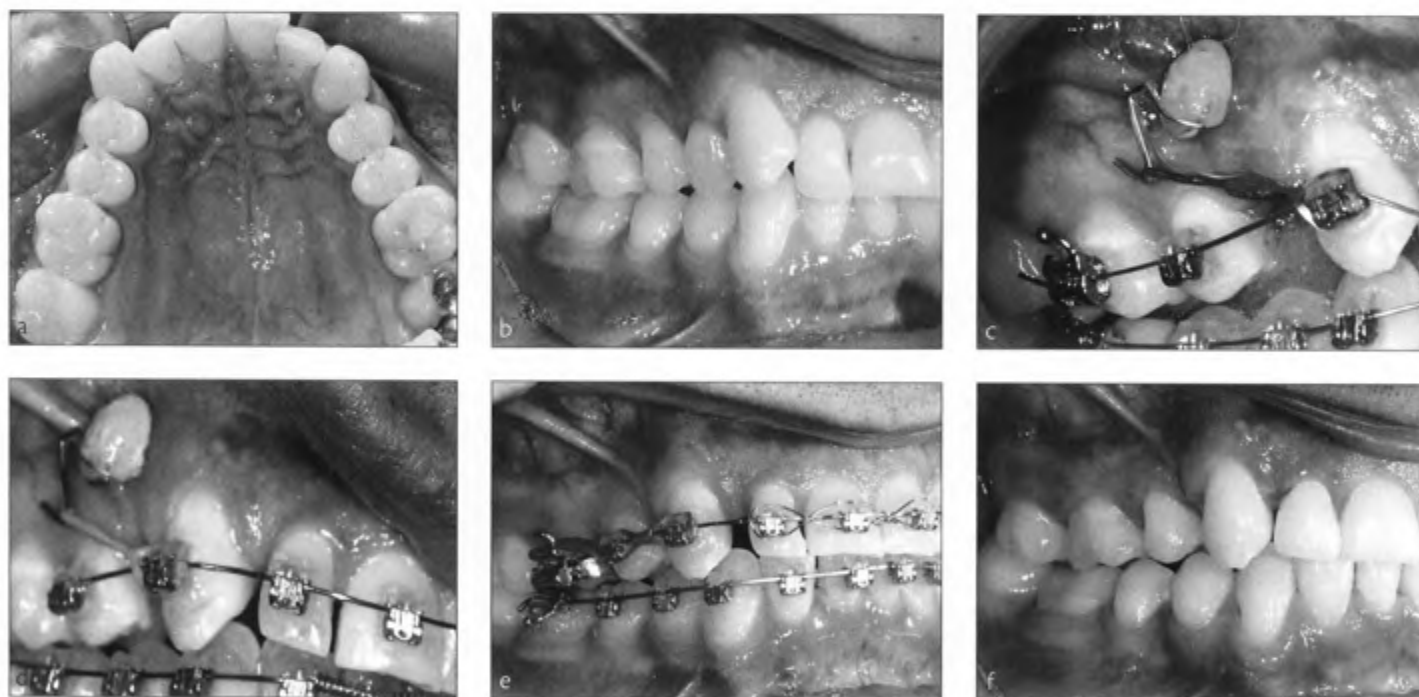


Fig. 8-24a to f A single mini-screw was used to retract the maxillary right canine subsequent to extraction of the right first premolar.

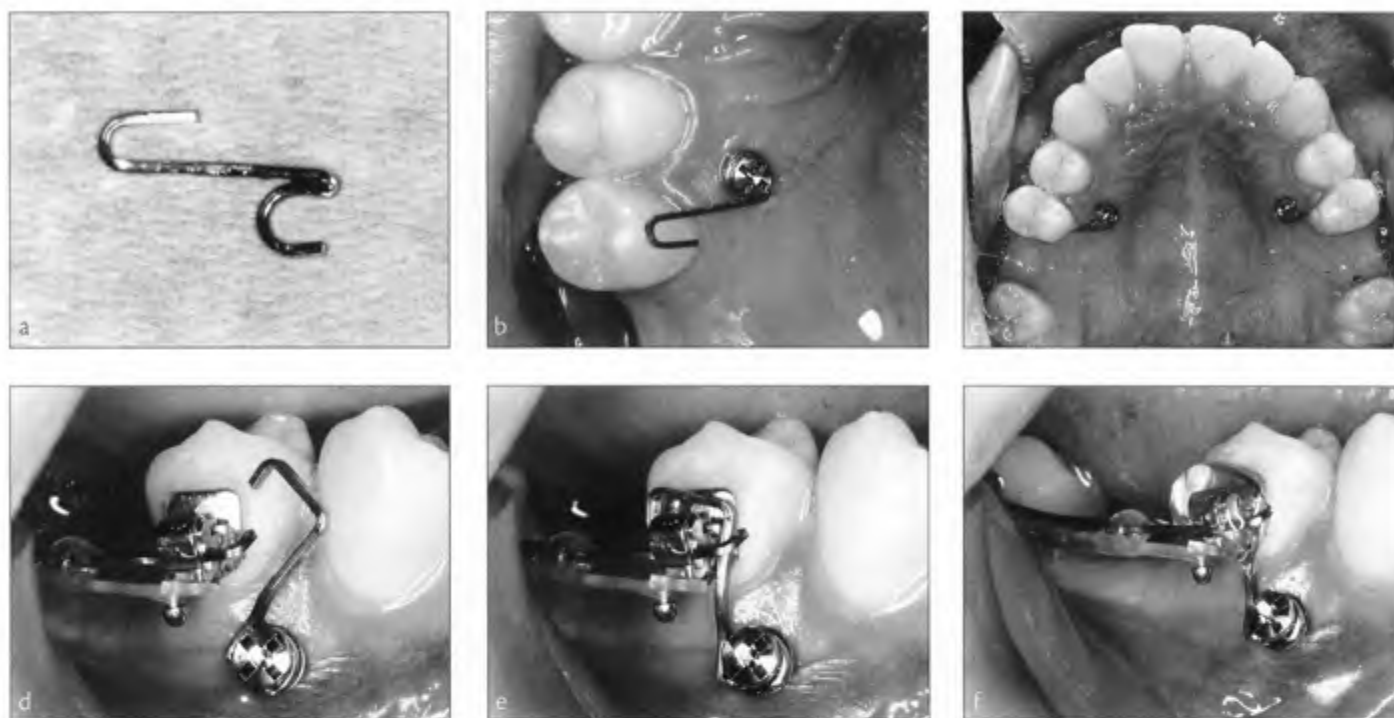


Fig. 8-25a to f The "tie-clip" mini-screw auxiliary (Winsauer, Bregenz) is designed to clip over the mini-screw, and then can be attached to a tooth with light-cured adhesive or snapped over an orthodontic bracket.

8.6.1 Uprighting Teeth

The most obvious applications for TAD-supported "uprighting" of teeth are for instances of mutilation. For example, uprighting a second molar may be accomplished to permit the prosthetic replacement of a missing first molar with a dental bridge or implant^{24,38/48}. Other related TAD-supported possibilities include:

- 1) Protracting (and uprighting) first molars through the sites of congenitally missing second premolars (Fig. 8-26)¹⁸
- 2) Protracting (and uprighting) second molars through the sites of previously-extracted first molars⁵⁰
- 3) Resolution of ectopic eruption by uprighting or protracting (e.g. impeded second molars)
- 4) Uprighting partially transposed teeth
- 5) Protracting or uprighting anterior teeth to resolve an anterior crossbite, reduce an overjet, or unilaterally to correct a midline deviation¹³.

8.6.2 Individual Labial Root Torque

Placing bends in a rectangular wire for the purpose of changing the labial root torque of an individual tooth (e.g. the root of previously palatally impacted canine that is still angled towards

the mid-palate) is a tedious exercise, painful for the patient, and features unintended reciprocal lingual root torque on the adjacent teeth.

The Compliance+ spring (American Orthodontics, Sheboygan, WI, USA) was designed to produce individual labial root torque without wire bending or adverse reciprocal torque⁶³. The Compliance+ is an auxiliary that is inserted into the vertical slot of a bracket (placed on the affected tooth; e.g. Butterfly System, American Orthodontics, Sheboygan, WI, USA) and then a round, stainless steel arch wire is inserted through the helical spring portion of the device and "tied" into the remaining brackets of the dental arch. An intermaxillary elastic is connected to the arm of the Compliance+ and then to hooks on brackets of the teeth in the opposing arch, directly above or below the affected tooth. The elastic produces forces to activate the spring, thereby rotating the root labially.

Unfortunately, the process is slow, requires absolute patient compliance, and could produce some adverse effects on the occlusal plane from extrusion. If, however, a mini-screw (featuring a head with some type of slot) is inserted near the affected tooth, then an L-shaped wire segment can be fixed in the slot (with light-cured adhesive) to depress or activate the spring without any requirements for patient compliance.

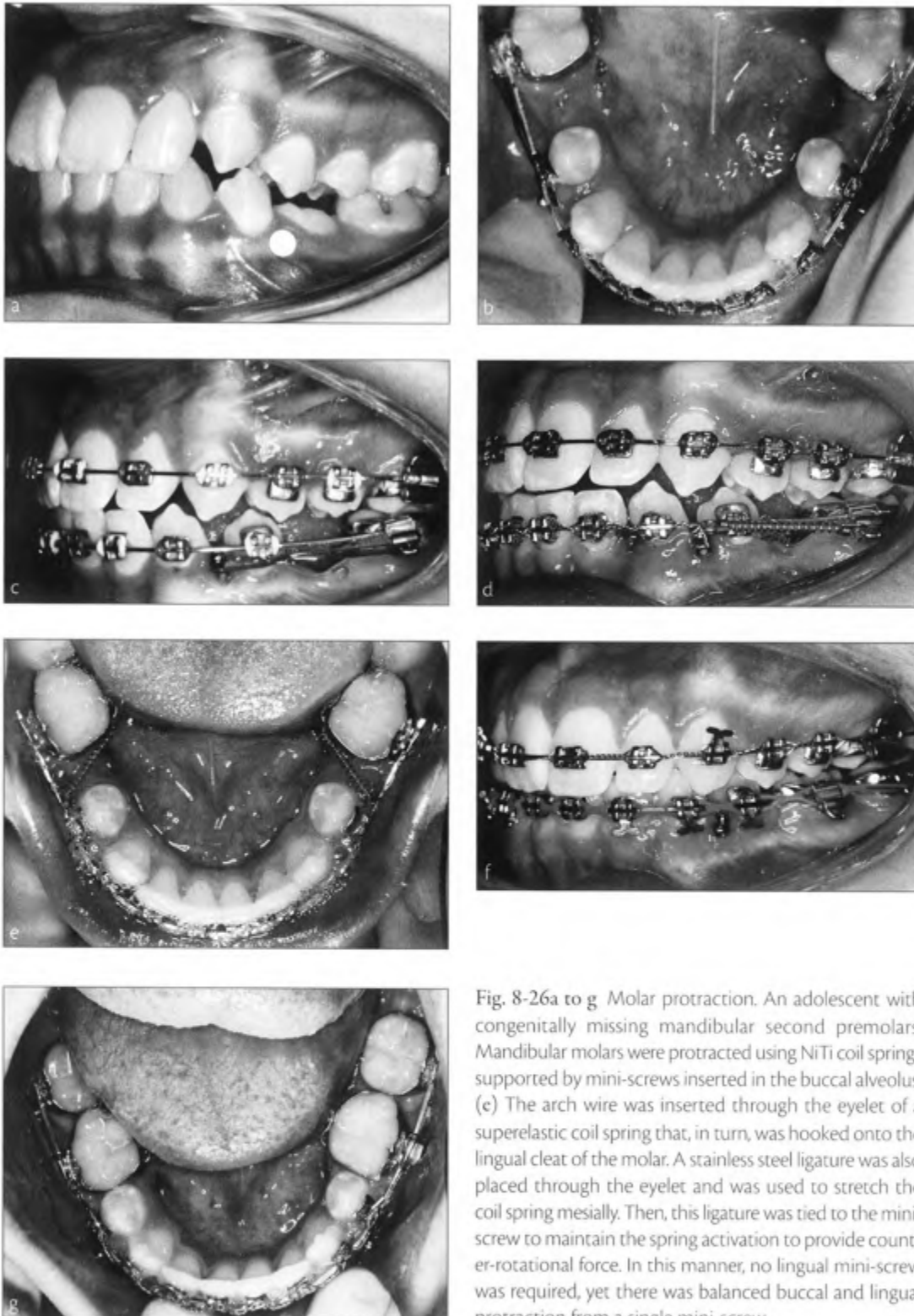


Fig. 8-26a to g Molar protraction. An adolescent with congenitally missing mandibular second premolars. Mandibular molars were protracted using NiTi coil springs supported by mini-screws inserted in the buccal alveolus. (c) The arch wire was inserted through the eyelet of a superelastic coil spring that, in turn, was hooked onto the lingual cleat of the molar. A stainless steel ligature was also placed through the eyelet and was used to stretch the coil spring mesially. Then, this ligature was tied to the mini-screw to maintain the spring activation to provide counter-rotational force. In this manner, no lingual mini-screw was required, yet there was balanced buccal and lingual protraction from a single mini-screw.



Fig. 8-27a to d Bite opening. An adolescent with a deep overbite was reluctant to comply with the use of headgear and, instead, chose the insertion of a mini-screw between the maxillary central incisors at the mucogingival junction. The mini-screw provided direct anchorage for intrusion of anterior teeth, using an elastic module, during the first 12 months of a 21-month treatment.

8.6.3 Individual Temporary Tooth Replacement

The replacement of missing single teeth is often problematic for growing individuals. If an osseointegrated implant is placed too soon, before the cessation of growth, then additional increments of vertical facial development may result in a restorative dilemma or poor esthetic result. Consequently, the adolescent patient that exhibits a congenitally missing lateral incisor or avulsed incisor presents a prosthetic challenge. Most often a transitional partial denture (i.e. "flipper" type of retainer with prosthetic teeth) must be worn to replace the missing tooth (or teeth) for perhaps several years until a permanent prosthetic bridge or implant can be inserted (an arbitrary age 15 for females or 19 for males)²⁴.

Graham²⁹ recently introduced an alternative to the "flipper" or bonded bridge, using mini-screws as temporary replacements for missing lateral incisors. A mini-screw is inserted into the same location that an eventual osseointegrated implant will be placed. A plastic denture tooth is selected and reshaped to fit the edentulous space. Then this tooth is "hollowed-out" with an acrylic bur to permit it to fit over the head of the mini-screw. Orthodontic bonding adhesive is then used to attach the prosthetic tooth to the mini-screw. Although this is a non-osseointegrated implant, it will still help to maintain the crestal and buccolingual thickness of the alveolar bone that is commonly lost from "disuse atrophy" in a long-standing edentulous site. After the cessation of growth, the mini-screw can be removed and the location for a prosthetic implant can be prepared.

8.7 Mini-screw Auxiliaries

Mass-manufactured auxiliary parts can be used to provide a quick coupling between mini-screws and teeth or orthodontic appliances. For example, preformed wire segments are commonly used to develop indirect mini-screw anchorage set-ups (Fig. 8-25). Certainly, the next level of mini-screw applications will involve the development of similar types of auxiliaries to eventually produce a toolbox of "Snap-On Tools" for use in a number of different treatment situations (e.g. tomas®-auxiliary kit).

8.7.1 Bite Openers

If given the choice, informed patients might now be inclined to opt for one or two TADs (producing constant intrusive force) rather than a year or more of 12–14 hour/day wear of a traditional headgear. As facial “jewelry” (with their attendant piercings) has become more popular for young adults in Korea, mini-screws have also become more acceptable as an alternative to extraoral anchorage with a headgear or “nightbrace”.

Either the upper or lower incisors may be intruded and/or the posterior teeth extruded

when correcting a deep overbite. Mini-screws can be used to facilitate the biomechanics of either alternative. For instance, maxillary incisors can be intruded using direct anchorage from mini-screws placed between the upper incisors, improving the smile line, reducing gingival display, and increasing incisal clearance. The intrusive force can be derived from elastic thread, elastic chain, or closed coil springs that are stretched from the mini-screw to the base arch wire (Fig. 8-27) or even from specially-designed auxiliaries (TAD Bite Opener Auxiliary, American Orthodontics, Sheboygan, WI, USA; Fig. 8-28).

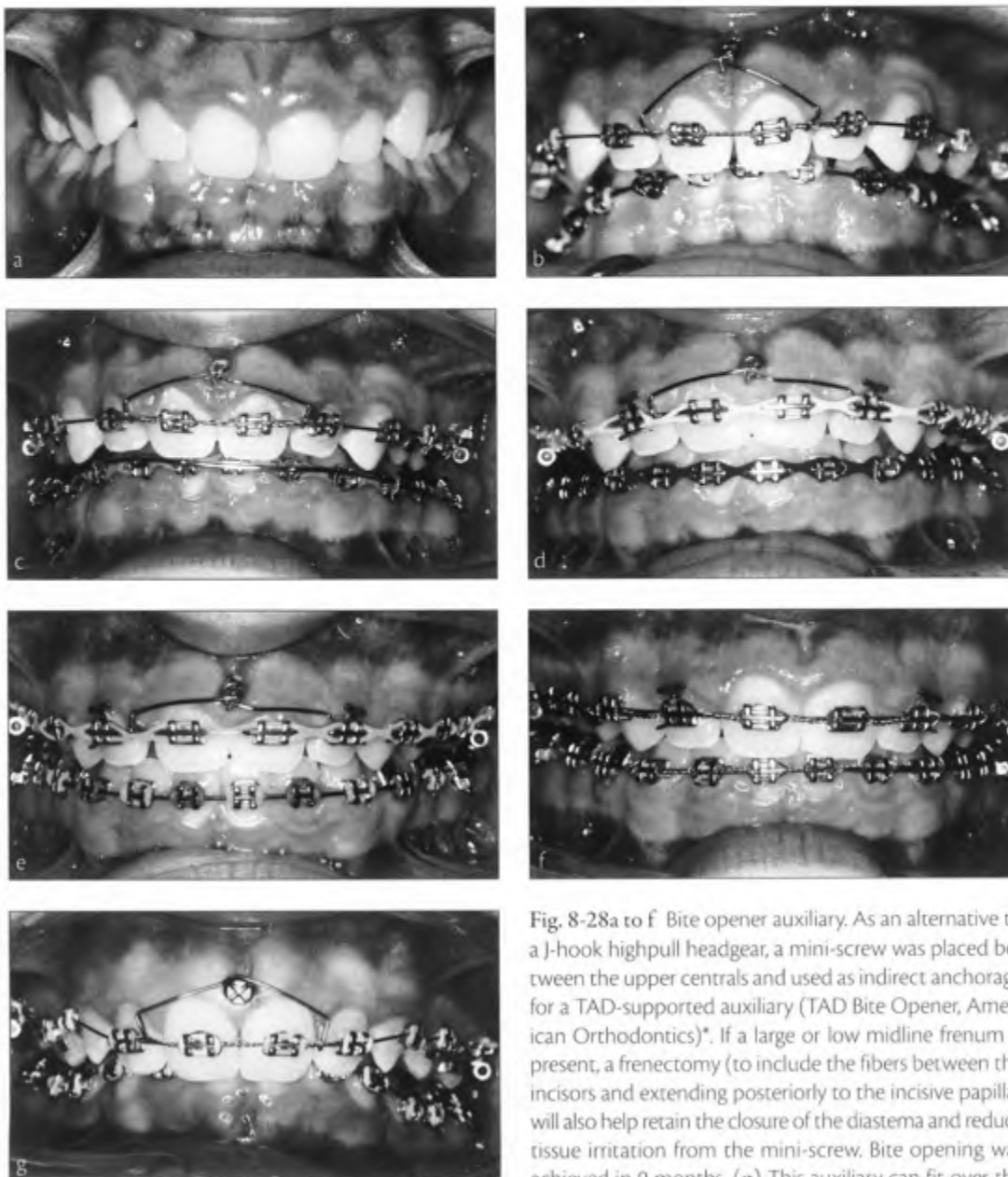


Fig. 8-28a to f Bite opener auxiliary. As an alternative to a J-hook highpull headgear, a mini-screw was placed between the upper centrals and used as indirect anchorage for a TAD-supported auxiliary (TAD Bite Opener, American Orthodontics)*. If a large or low midline frenum is present, a frenectomy (to include the fibers between the incisors and extending posteriorly to the incisive papilla) will also help retain the closure of the diastema and reduce tissue irritation from the mini-screw. Bite opening was achieved in 9 months. (g) This auxiliary can fit over the head of most available mini-screws (e.g. Aarhus).

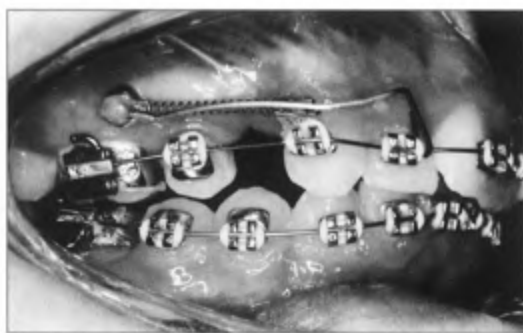


Fig. 8-29 Intrusion and retraction. Segmental intrusion arms attached to mini-screws with light-cured adhesive. Note: Retraction coil springs and simultaneous intrusion from the same mini-screws. Several applications can be served at the same time from the same mini-screw.

Another option for intrusion of anterior teeth involves placing mini-screws between posterior teeth (first molars and second premolars) to support a continuous intrusion arch wire or even sectional intrusion arms (Fig. 29).

Paik and co-workers⁶ have reported improvement in vertical maxillary excess (VME) by differentially intruding the *entire* maxillary dentition. This type of change was typically thought to be possible only with orthognathic surgery. Lin and colleagues⁵² also demonstrated substantial improvement in so-called "gummy smiles" using mini-screw anchorage (Fig. 8-30).



Fig. 8-30a to d Intrusion of the maxillary anterior teeth using mini-screw anchorage to improve the "gummy smile" for an adolescent patient. Mandibular mini-screws were used to intrude posterior teeth to control vertical dimension.

8.7.2 Bite Closers

In some instances, a combination of mini-screw supported posterior intrusion and anterior extrusion may be required to close an openbite, improve the smile line or occlusal plane, or to merely maintain the mandibular plane angle. There have been only a few devices designed to extrude teeth using forces directed from apical to the occlusal plane (e.g. MEAW). Two extrusive TAD-based auxiliaries, the "short" Propeller Arm (Fig. 8-31) and the Ulysses spring (American Orthodontics, Sheboygan, WI, USA; Fig. 8-32), were developed by *Anka*⁶ and *Bowman*¹³ to achieve this effect.

8.7.3 Propeller Arms

Protracting, advancing, or pushing teeth anteriorly is another orthodontic tactic that benefits substantially from mini-screw anchorage. *Anka* and *Bowman* created a TAD-based protraction arm ("long" Propeller Arm, American Orthodontics, Sheboygan, WI, USA; Fig. 8-21g, Fig. 8-33) to produce mesially directed forces to advance incisors, support protraction of posterior teeth, and to assist in the resolution of midline deviations (asymmetries). The compressed coil spring from the Propeller Arm is supported by the mini-screw and directed to the base-arch wire, to a "power arm", or directly to specific teeth.



Fig. 8-31a to d Open bite closure. Maxillary midline mini-screw was placed after frenectomy. A "short" prototype Propeller Arm (American Orthodontics, Sheboygan, WI, USA)* extrusion spring was used to reduce the openbite. Cosmetic "bonding" of the narrow lateral incisors was completed after orthodontic space consolidation.

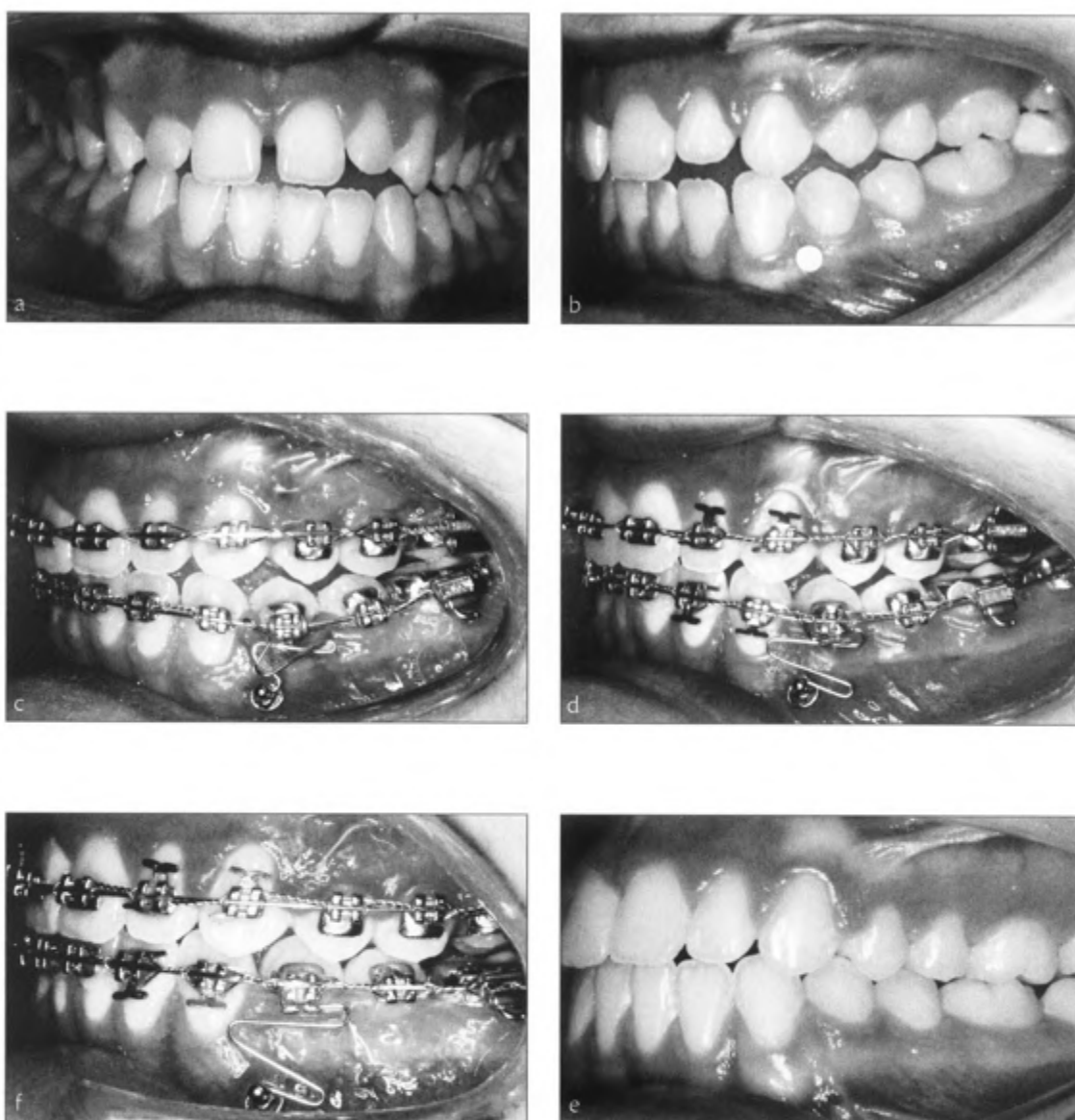


Fig. 8-32a to f Open bite closure. Ulysses spring auxiliary (American Orthodontics, Sheboygan, WI, USA)* was compressed between a mini-screw and the arch wire to close a lateral openbite.

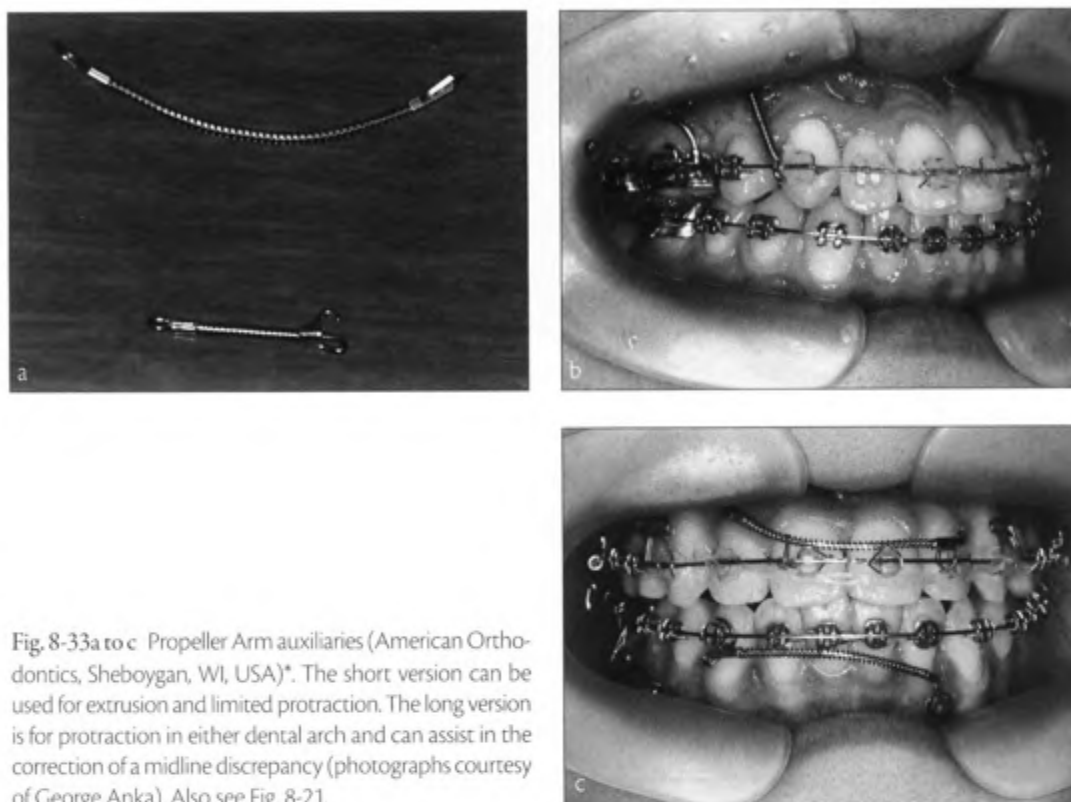


Fig. 8-33a to c Propeller Arm auxiliaries (American Orthodontics, Sheboygan, WI, USA)*. The short version can be used for extrusion and limited protraction. The long version is for protraction in either dental arch and can assist in the correction of a midline discrepancy (photographs courtesy of George Anka). Also see Fig. 8-21.

8.7.4 Pushmi-Pullyu Mechanics

In some instances, a combination of posterior or protraction and anterior advancement may be required. If a mandibular first molar or second premolar is missing, the anterior teeth may have collapsed lingually, with a corresponding increased overjet or a midline deviation. Protraction of the molar, along with concurrent uprighting ("flaring"), advancement, or de-compensation of the anterior teeth may be needed. One mini-screw can be used for both applications (Fig. 8-34). This dual mechanism has been dubbed the "Pushmi-Pullyu" method, named for Hugh Lofting's *two-headed animal*, introduced in the 1948 novel, *The Story of Dr. Doolittle*.

8.8 Final Considerations

We have to continually be jumping off cliffs and developing our wings on the way down
Kurt Vonnegut

The introduction of mini-screw anchorage in orthodontics has signaled the start of a significant paradigm shift. Traditional orthodontic mechanics and treatment options may be substantially altered in many situations where more effective, efficient, and predictable TAD-supported directional forces could be used. Although we are early in the adoption and evolution of mini-screw use, the recent number of publications and continuing education courses (and their significant attendance) signals that we have reached the "tipping point"³⁷, where rapid assimilation of this technology will now likely transpire. The day will soon come when orthodontists will wonder how some treatments were ever accomplished without the advantage of mini-screw anchorage.

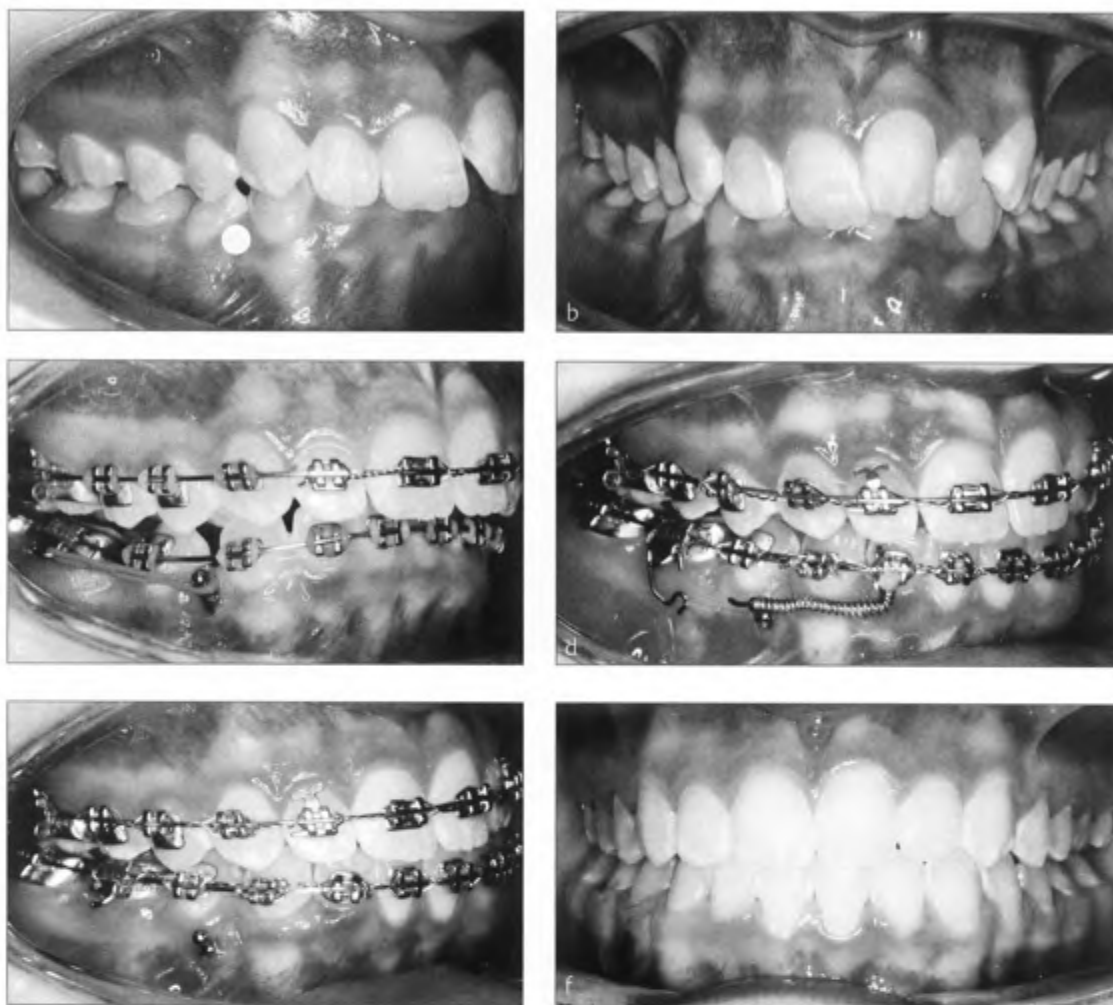


Fig. 8-34a to f One mini-screw was used for two purposes simultaneously ("Pushmi-Pullyu" mechanics): 1) protraction of the molars into the site of a congenitally missing second premolar, and 2) pushing the mandibular dentition to the left to correct the midline discrepancy.

* S. Jay Bowman has a financial interest in this device.

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